BRL

REPORT NO. 1331

THE ELECTROMAGNETIC PROPAGATION RANGE FACILITY AT THE BALLISTIC RESEARCH LABORATORIES

by

Channing L. Adams

July 1966

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U. S. ARMY MATERIEL COMMAND
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

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Channing L. Adams

Ballistic Measurements Laboratory

RDT&E Project No. 1P523801A286

A B E R D E E N   P R O V I N G   G R O U N D,   M A R Y L A N D

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CLAdams/ss
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ABSTRACT

This report describes the instrumented range facility designated the Electromagnetic Propagation Range as established by the Ballistic Research Laboratories (BRL) in support of fundamental research in the near-earth meteorological environment. It includes a description of the multi-channel, high-speed, digital data acquisition system, the types of instrumentation used for obtaining meteorological data, methods of instrument and sensor calibration, and typical results of field programs. Tabulated data and photographs of all parts of the system are included.

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I. INTRODUCTION

In the spring of 1963, the Ballistic Measurements Laboratory of the Ballistic Research Laboratories (BRL) undertook the establishment of an instrumented Electromagnetic Propagation (EMP) range facility in support of fundamental research in the near-earth meteorological environment. The purpose of this facility was the acquisition of meteorological and supporting data necessary for the establishment of design parameters and the performance evaluation of target detection and discrimination, tracking, guidance and homing concepts. It was desired that in addition to obtaining meteorological data the facility should have the capability of supporting research in both optical and electronic measurements already being carried out by laboratory personnel.

The plans for the EMP range facility were formulated by cooperation of all those at BRL interested in this type of research. As work has progressed, other laboratories and agencies have expressed an interest in the facility. It is the purpose of this report to describe what has been accomplished to date in the fulfillment of the original mission and to briefly outline future plans. It is expected that changes will be made in the facility as research data are evaluated, as instrumentation is improved, and as requirements are modified.

II GENERAL DESCRIPTION

The EMP range facility is located, as shown in Figure 1, on Spesutie Island in the vicinity of Locust Point, approximately 2 miles east of the mainland of Aberdeen Proving Ground. This location is bounded on the north and east by the upper section of Chesapeake Bay; there are no natural obstructions to impede air flow. On the west side, the range boundary is a swampy area with a thin row of trees extending about one-half the range length. Directly south, there is an open area approximately 3/4 mile long which is quite flat and also offers very few obstructions.

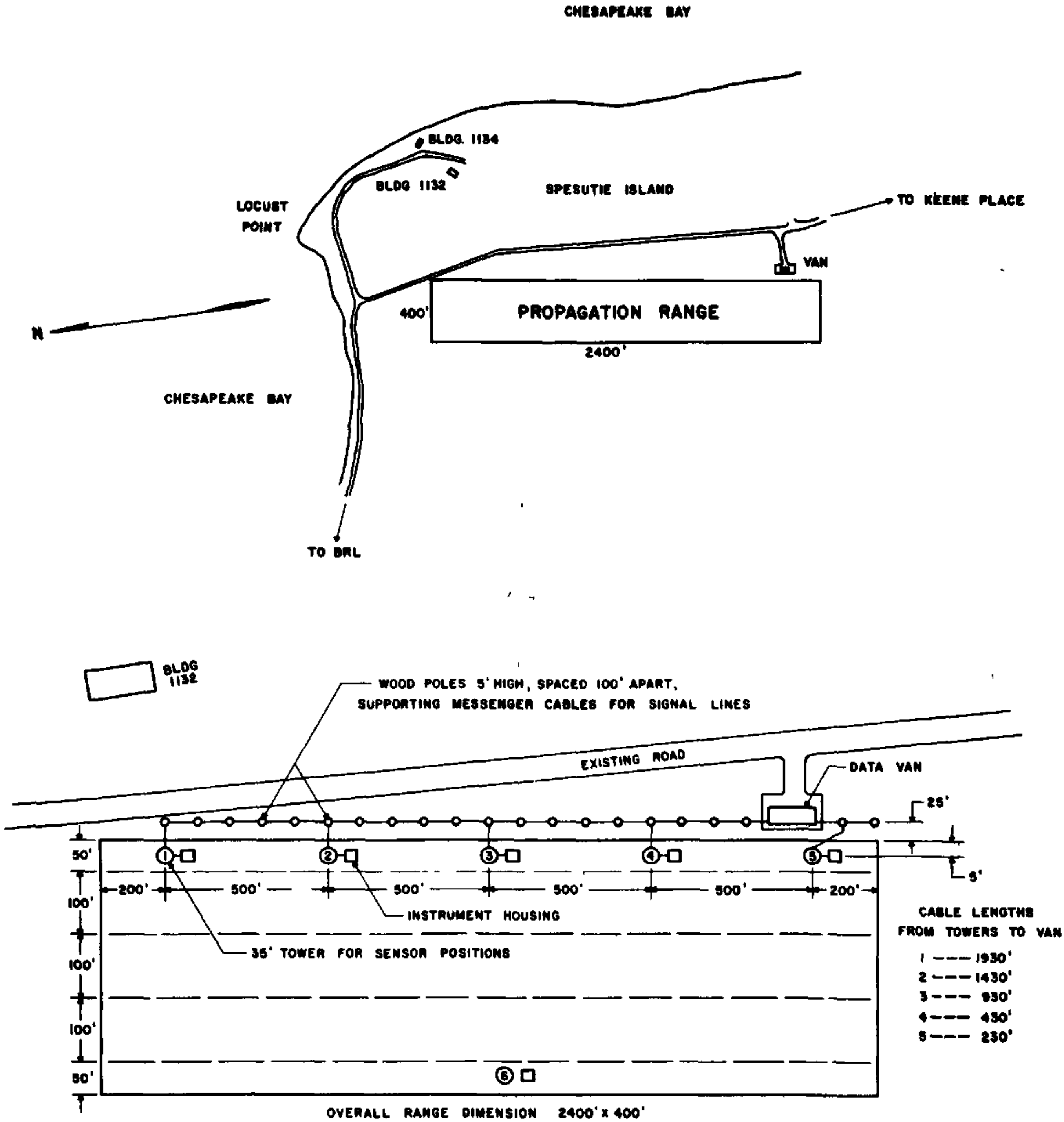


FIG. 1 - ELECTROMAGNETIC PROPAGATION RANGE AT LOCUST POINT, SPESUTIE ISLAND

In order to establish similar ground conditions over the entire range, an area 2400 feet long and 400 feet wide was scraped and graded to a nearly flat surface, with the west side just slightly lower than the east side, for drainage purposes. Area is available to allow future extension of the range length to 10,000 feet over land and to approximately twice this distance over water. The longitudinal axis of the range is aligned 8 degrees east of Magnetic North. Since the prevailing winds in this region are westerly and northerly, the air flow is generally across the narrow section of the range area. At both the north and south ends of the range are located roadways leading to areas on which instrument shelters and vehicles may be placed for target detection and discrimination tests. Necessary ac power is available at outlets conveniently placed near these areas. Figure 2 shows a general view of the range when looking toward the southwest.

Five 30-foot steel towers, mounted rigidly on concrete piers, are spaced 500 feet apart on the eastern edge of the range. Attached to the towers at three levels are six-foot sections of 2-inch square aluminum conduit. The manner of attachment allows sensors to be mounted at each end of the conduit and away from the tower itself. Figure 3 shows one of these towers with two sensors per level mounted at 6, 12 and 30 feet above the ground. These sensor mounts can be easily moved as program requirements change. In addition, the towers are hinged at a point 15 feet above ground level to allow the upper section to be lowered for easy access to cables and sensors. Figure 4 shows one of these towers in the lowered position. After the initial calibration of the sensors is made, they are installed in the desired configuration on these towers. Signal cables from the sensors are brought down the tower and fed into instrument housings, or shelters, where they are connected to amplifiers, power supplies, or bridge circuits depending upon the type of sensor in use. The outputs of the sensor circuits are connected to terminal strips in a junction box to which are attached the long signal lines leading to a data acquisition system located in an instrument van placed 30 feet away from the east side of the range and about 400 feet from the southern end.

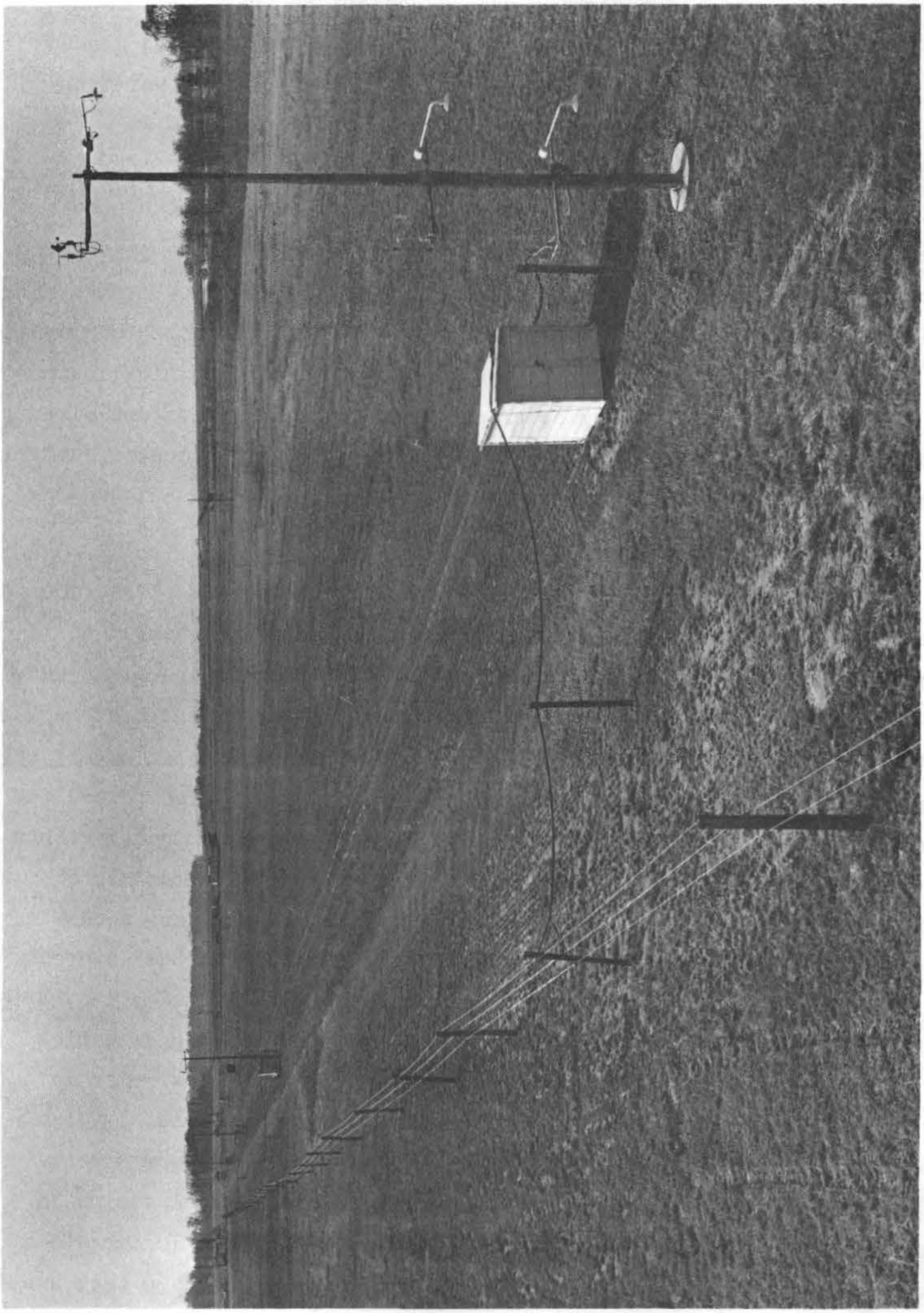


FIG. 2 - OVERALL VIEW OF RANGE FACILITY

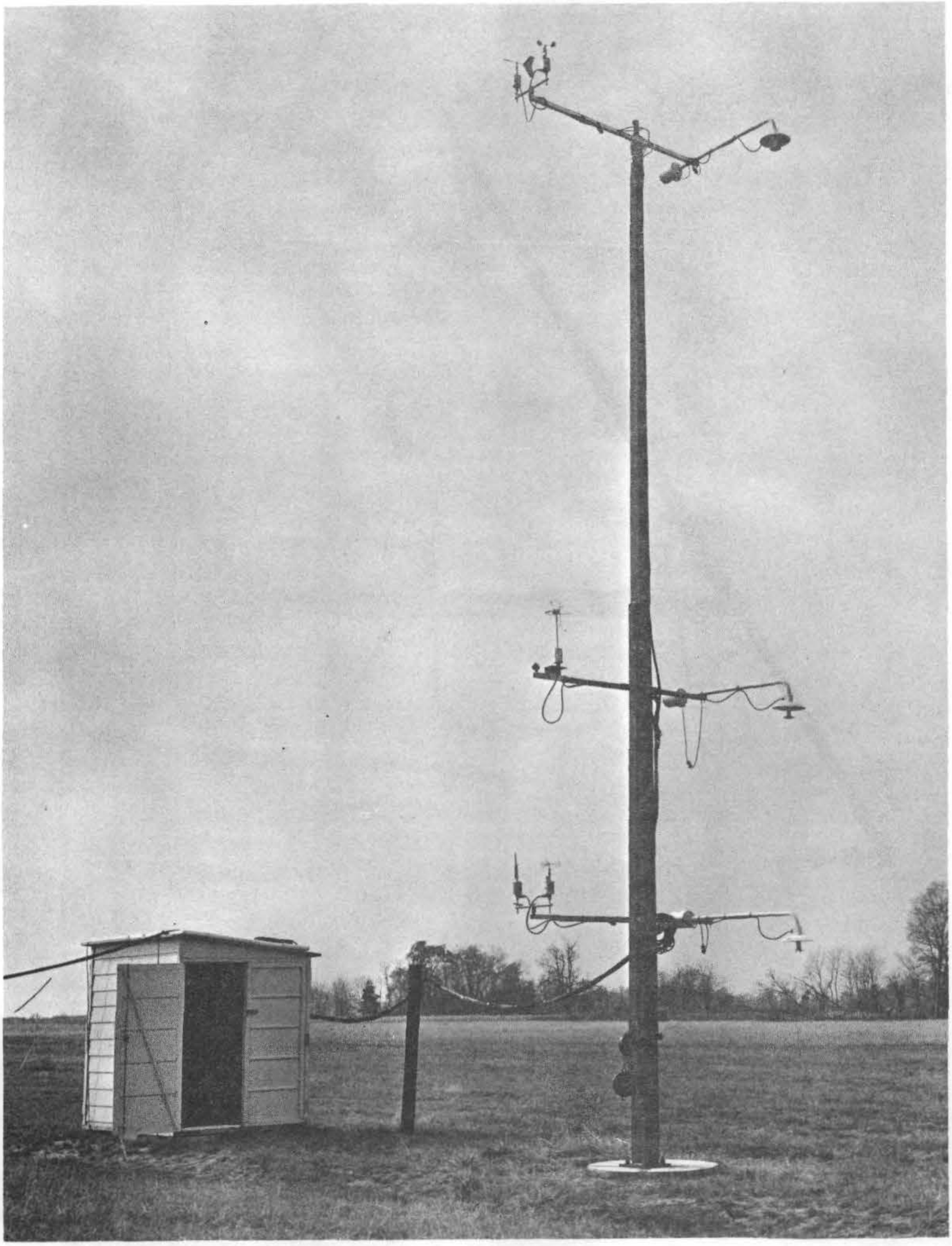


FIG. 3 - SENSOR TOWER AND INSTRUMENT SHELTER

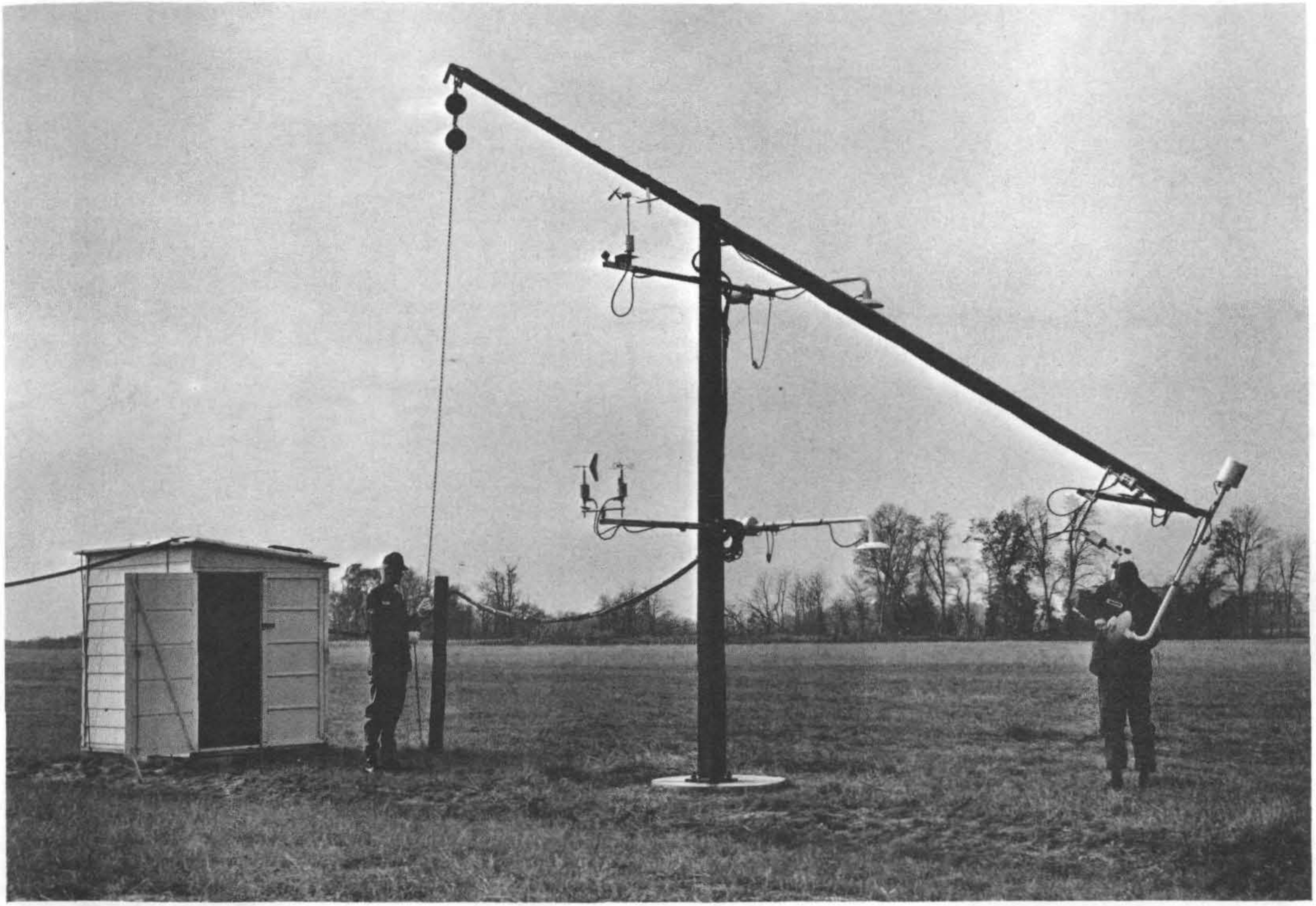


FIG. 4 - SENSOR TOWER IN LOWERED POSITION

The signal cables are routed to the van on a pole line paralleling the east side of the range and are fastened to a steel messenger cable which is attached to the supporting wooden poles, spaced 50 feet apart. Power and intercom lines are carried to each tower location on a separate messenger cable on the same pole line. As is shown in Figure 2, the poles supporting the cables are only five feet high. Thus, a man standing on the ground can service the cables.

Each of the two signal cables contains multiple pairs of lines for a total capacity of 24 channels per tower location. The line for each channel consists of a plastic-insulated, twisted-pair, 22-gauge wire with a drain, or shield, wire. Each pair plus drain is individually shielded from other pairs in the same cable by an aluminum foil wrapping. A high dielectric strength coating material is on the outer surface of the foil and provides isolation between shields of adjacent groups. This type of cable greatly reduces cross talk and spurious signal impulses, and provides a reduction of common mode voltages usually found in long cable installations.

The signal lines are terminated in jack panels at the data acquisition system, where it is possible to patch any sensor to any desired data input channel.

Prior to the tower installation, several data runs were made with sensors located on 14 five-foot tripods placed 100 feet apart along the east side of the range. The signal cables at each instrument housing were used to obtain an overall test of the system. The objective in the field layout was to provide a system which was flexible enough to meet the ever-changing user requirements encountered in research programs.

III. DATA ACQUISITION SYSTEM

In the planning stages for the EMP range, it became apparent that severe limitations would be placed on the acquisition of data from a large number of sources if conventional methods of recording data on charts were used. Hence, it was decided that performance specifications would be written for a data acquisition system using up-to-date digital techniques with the output data recorded on magnetic tape. The problem then became one of determining such factors as sampling rates, conversion speed, number of channels, tape format, and input levels. The system obtained was manufactured to BRL specifications by Astrodata, Inc. of Anaheim, California and was delivered in April 1964. The system was installed in a 40-foot van located near the southeast end of the range. Figure 5 shows the present system contained in three equipment racks, each with two bays. Viewed from the front, the first bay on the left contains a Potter Model 906II-2 tape transport with its associated amplifiers, control circuits, and power supplies. Directly below the transport is the patchboard used to provide the desired digital programming. The second bay of the first rack contains the system control panel from which all operations are controlled. Below the panel are the card modules for holding the individual solid-state circuit cards required in the system. The system DC power supply is mounted directly under the lower card module.

In Rack No. 2, the first bay houses two analog-to-digital converters, the multiplexer logic cards, and an analog plug-board to allow external monitoring and chart recording of selected data channels. The second bay of this rack contains 72 of the system's signal-conditioning amplifiers with associated power supplies. A modification of the original cabling system has been made by the addition of a patch panel, shown directly above the amplifiers in this bay. Each field line is connected directly to this panel and may be patched to any input desired. If any other circuit is required to be inserted into the system prior to entrance to the data acquisition section, this patch panel provides this capability, thus, increasing the versatility of the system.

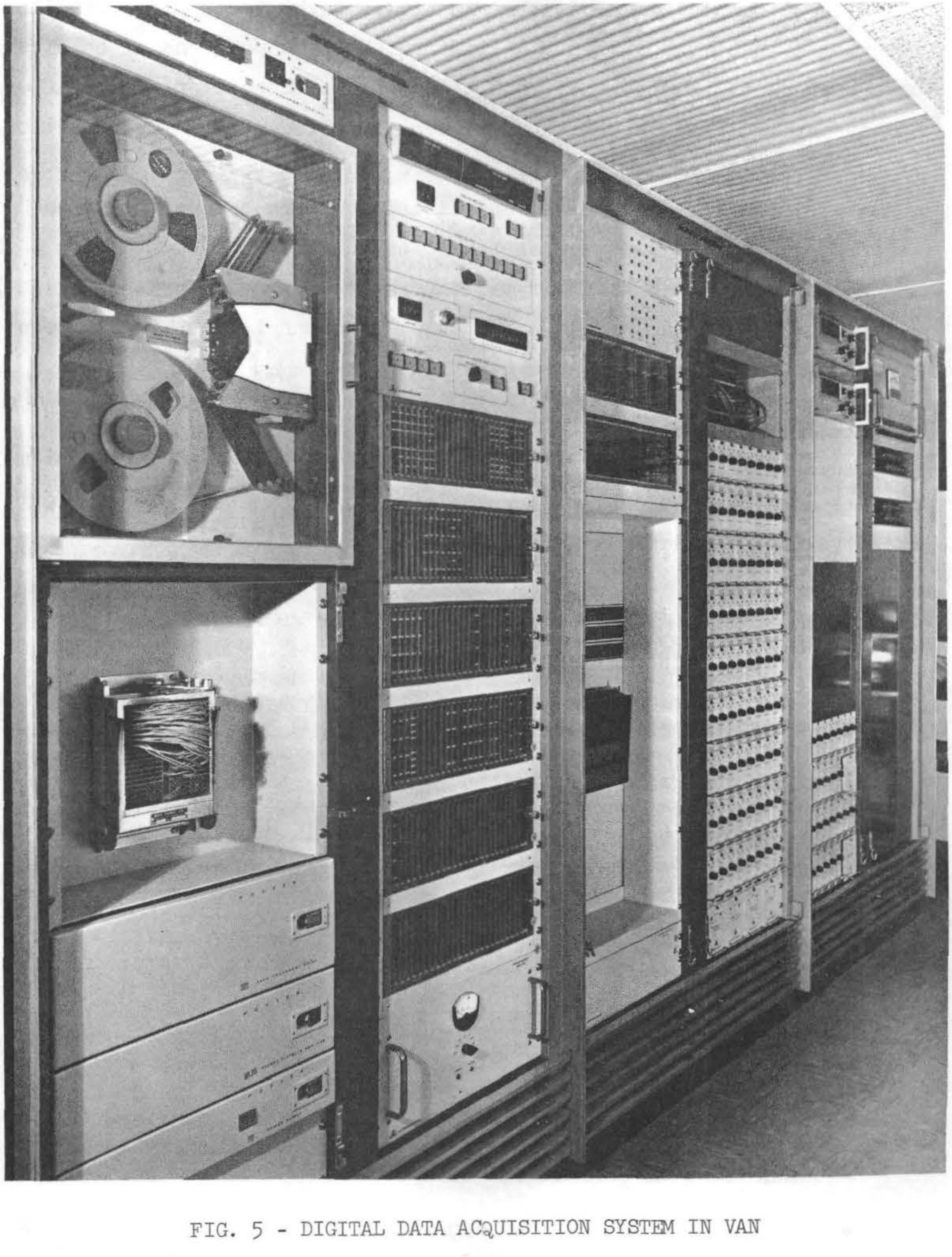


FIG. 5 - DIGITAL DATA ACQUISITION SYSTEM IN VAN

The third rack was installed initially without equipment to allow future growth of the system. At the present time portions of both bays have been used. Twenty-eight additional signal-conditioning amplifiers and associated power supplies have been installed in the lower section of Bay No. 1. At the top of this bay are located two DANA digital volt-ohmmeters used for calibration and circuit testing before the field sensors and circuitry are connected to the data acquisition system. The second bay contains a bridge-type temperature measuring system utilizing a separate resistance bridge for each of 18 channels, the bridge power supplies, amplifiers, and test circuits.

A. System Capabilities

The basic function of the data acquisition system is to accept multi-channel analog voltages in the range of 0 to ± 5 volts DC, to convert these voltages to digital form at high speed, and to record the digital information on magnetic tape in a format compatible with an IBM type 1401 digital computer.

The system capabilities are as follows:

- Input analog data may be digitized at a maximum rate of 20,000 samples per second.
- The digital section of the system has been designed to accept 150 analog channels. At present the system contains 100 input signal-conditioning amplifiers and has space available for future expansion to the maximum of 150.
- The conversion of the analog input signals into their decimal equivalents is accomplished by the use of two analog-to-digital converters, (ADC) each operating at a 10 Kc/s sample rate. The two converters alternately digitize the input signals in a manner to produce a 20Kc/s sample rate. The ADC's are bi-polar four-decimal digit devices. The ADC digital word is zero output and ±4999 counts for a ± 5 volt input to the ADC.
- The signal conditioning amplifiers are of the potentiometric-input differential type arranged on an amplifier-per-channel basis, with selectable gains of 1, 2, 5, 10 and 50.
- Utilizing a built-in, adjustable, precision calibration power supply, pre-run and post-run calibrations of the overall system may be made.

- There are two basic modes of system operation; the first is an on-line mode in which input data obtained from field-located sensors are digitized, put in the proper format, and recorded on magnetic tape; the second allows two types of monitoring for troubleshooting and adjusting parameters of the overall system.

- A built-in time accumulator, functioning from either internal or external signals, is provided to produce time words for recording on the tape with the digitized analog data.

- Provision is made for a visual display of the digital values of selected data channels, a display of channels in error, and an error counter. The system contains circuits that compare the output of the analog section of the system with selectable "error limits" circuits and that indicate out-of-limit channels.

- Circuits for read-after-write parity-error detection are included.

- The insertion of 12 digits of preset title, or identification, data on magnetic tape can be accomplished by simple front-panel switch operation.

- All systems controls are adequately interlocked so that out-of-sequence operations are not possible.

- An independent performance analyzer channel is provided for checking digital operation of the system. This channel is read back from the magnetic tape and an error is indicated by the error counter if there is a difference between the word read and a pre-set voltage.

B. <u>Circuit Description</u>

Figure 6 is a simplified block diagram of the system and serves to indicate the basic sections for illustrative purposes only. The logic involved in the system layout is not a part of this drawing.

Signal cables from the sensor outputs located at the field sites enter the acquisition system through plug connections and are then routed to jack panels in Rack No. 3 by Bay No. 1. This allows patching of input channels in any desired configuration into the system's input transfer switches. These switches transfer the signal, the signal return, and the guard lines for each sensor from the input of each signal-conditioning amplifier to the output of the precision calibration power supply when desired. During data gathering runs the switches are in the proper position to allow direct input to each amplifier, which operates

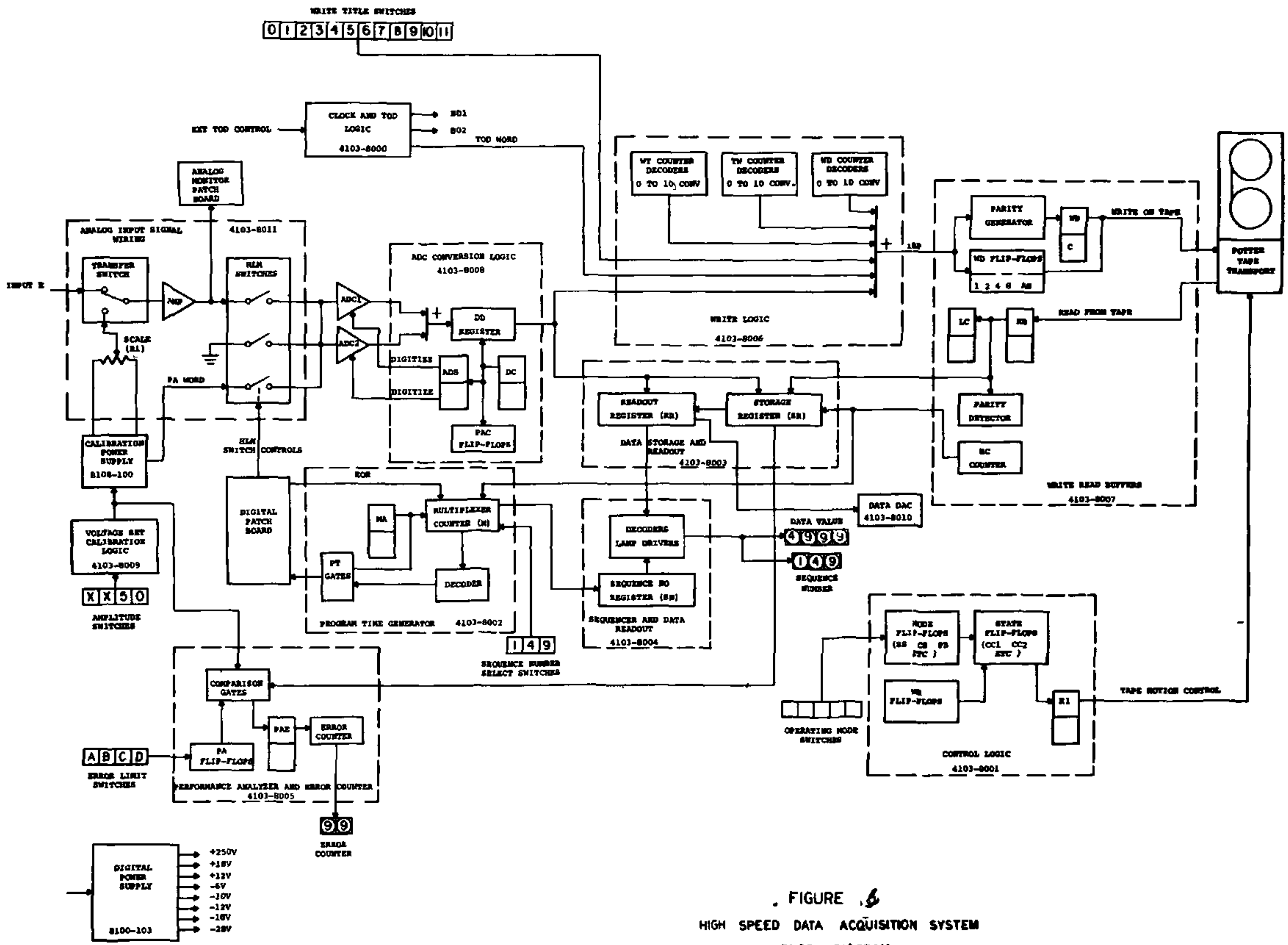


FIGURE 6

HIGH SPEED DATA ACQUISITION SYSTEM

BLOCK DIAGRAM

FIG. 6 - BLOCK DIAGRAM OF DATA ACQUISITION SYSTEM

with an input impedance of 1000 megohms and with an output voltage range of ± 5 volts. The outputs of the amplifiers are connected to an analog patchboard so that recordings may be made on external analog recorders. Eight Esterline-Angus chart recorders have been installed in racks adjacent to the data system for this purpose.

From the analog patchboard, the signals are routed to a 150-position high-level multiplexer which sequentially switches multiple inputs to a common output bus. Control of the multiplexer is provided by a digital patchboard shown in Figure 7. The positions marked Program Times are the outputs of the 150 position sequencer and this determines the order in which channels will be digitized. On the right side of the digital patchboard are groups of 25 connections, each marked with site numbers. These connections are the inputs to the multiplexer from each field position where the sensors are located. Thus, any sensor at any site may be patched into any program time desired. This allows great flexibility in the order in which the input signals may be selected for digitizing. The patchboard sections indicated as HUBS are 20 connections wired in parallel. By proper patching of up to 19 program times into one HUB section with the remaining HUB connection patched to a specific site position, the sensor at that position will be scanned 19 times. This in effect is super-commutating a single sensor. There are two patchboard parallel connections labelled E-O-R for end of record operation and these allow one to short cycle the sequencer. Use of these positions makes it unnecessary to operate through 150 positions for each scan, if this is desired. The length of the scan is determined by the sequencer position into which one has connected the EOR connection. Referring again to the block diagram, the common output of the multiplexer is connected to the parallel inputs of two analog-to-digital converters (ADC) which serve as the interface between the analog and digital sections of the system. The ADC's convert the scanned analog input voltage to proportional binary-coded decimal (BCD) numbers by sequentially comparing the input current with precise, digitally-weighted currents that are generated within the ADC's. The output and display of each converter is four

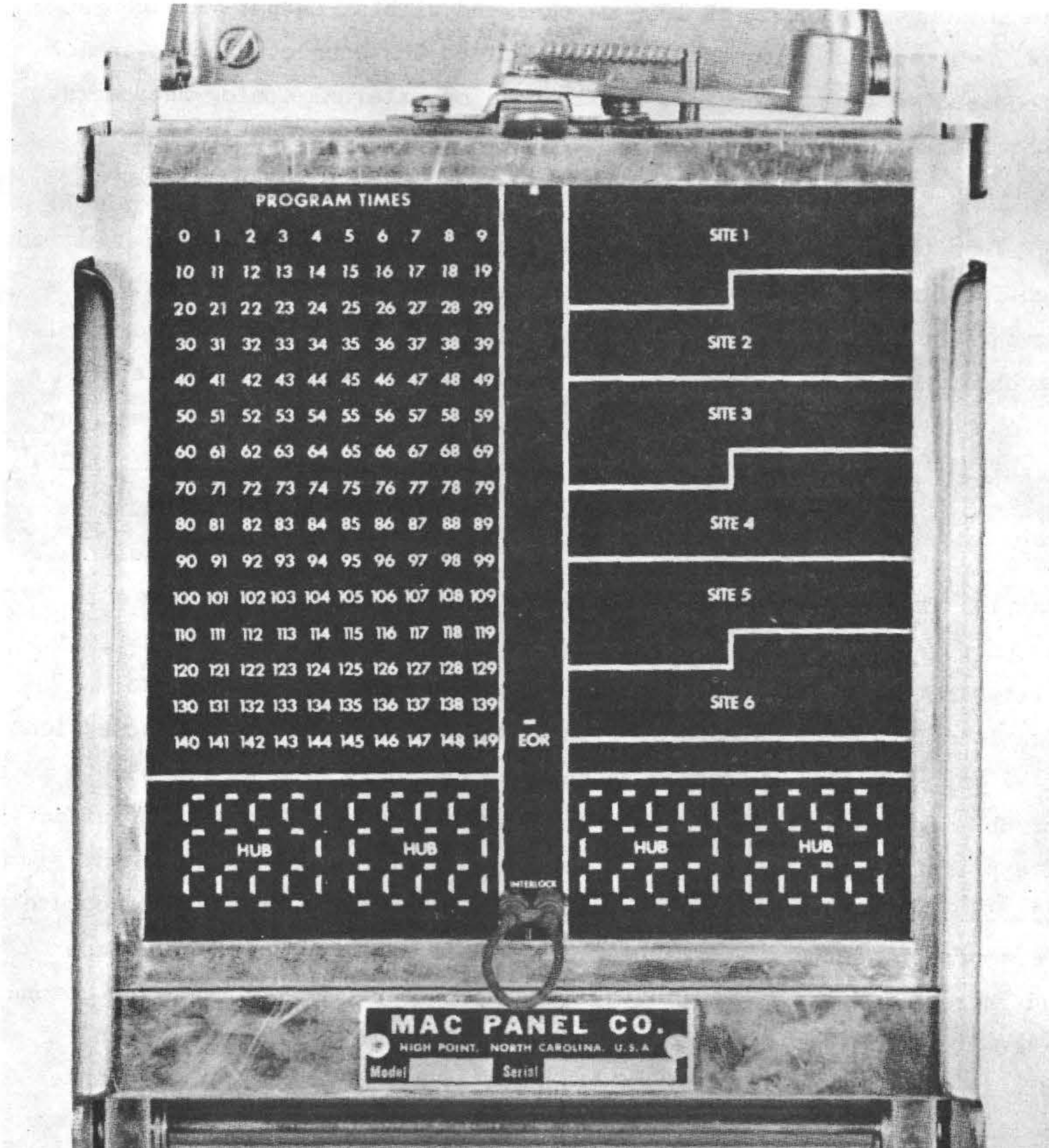


FIG. 7 - DIGITAL PATCHBOARD

decimal digits and sign. For present range operations the converters are operated unipolar, although they have the capability of bi-polar operation. They are calibrated such that a ± 5 volt input produces ±4999 counts output.

The outputs of the two ADCs are alternately selected to be stored in a digital data register. The output of this register is connected to write-logic gates, a readout register, and a storage register.

Words are written on magnetic tape in IBM gapped format, a seven-bit character at a time. The system has three output word sources, each parallel in character; these are the digital data register, timing logic, and title data switches. The write logic converts the parallel words to serial characters, adds necessary pad characters required by the format, and processes the characters for writing on the magnetic tape. In addition a parity generator is included to determine the number of bits in each character and, when necessary, to add a bit to make an even count.

To ensure that each character has been written properly on tape, the system reads each character after it has been written and performs both vertical and longitudinal parity checks. When operating in the playback mode, selected channels may be read from the tape and displayed on front-panel nixie-type indicators. Provision is also made for the first word in each data record, known as the performance analyzer (PA) word, to be read and compared with a precise input voltage to check the accuracy of the digital section of the system. If a difference exists between the PA word and the known value, an error is shown by front panel indicators. The amount that the output of the system may vary about the selectable, precise input voltage is determined by settings of front-panel error switches, labelled A, B, C and D. The errors are respectively 0.1 percent or 5 counts, 0.2 percent or 10 counts, 0.3 percent or 15 counts and 0.4 percent or 20 counts. The known precise input voltage is selected by amplitude switches and a scale potentiometer on the front panel. Identification of data words is accomplished to allow the storage register to load the words in the proper sequence and to

control the multiplexer through a counter. The output of the storage register is connected to the readout register and comparison gates. The readout register controls the front panel data display indicators, and a sequence number register controls the front-panel sequence number indicators.

System timing is derived from a 160 Kc/s, crystal-controlled oscillator, the frequency of which is halved to 80 Kc/s to provide the required control pulses. Further division to 10 Kc/s provides the system's time-of day clock for writing on tape at the beginning of each data word. This section may be operated from an external 10 Kc/s precision source if desired. Time is provided from hundredths of milliseconds to tens of seconds. System control advances the logic in a fixed sequence for specific modes of operation, such as writing end-of-file and end-of-tape characters, generating start, stop and reset signals and the playback mode.

C. Digital Tape Recorder

The magnetic tape recorder/reproducer furnished with the data acquisition system consists of a Potter 906II-2 high speed digital tape transport with associated M3323 drive electronics, M3321 manual control unit, and MA 315 record and reproduce amplifiers. The transport is of the standard digital type with a tape drive system generating the motion required to move 1/2-inch wide tape across the record/reproduce heads under control of the system logic. This allows fast start time of no more than 3 milliseconds, a tape speed of 150 inches per second, and a fast stop time of no more than 1.5 milliseconds. Rewind tape speed of 300 inches per second in either direction for 1/2-inch tape . Local operation of control functions such as rewind, forward, stop and the like, is available on a control panel. Automatic control of system functions is routed through the circuit from the system logic. Associated functions such as start-of-tape indication, low tape supply, and end-of-tape indication and control are also provided. The purpose of the record/reproduce amplifiers is to record on the magnetic tape the digital information provided in a particular format from the acquistion system, and to reproduce this data on command.

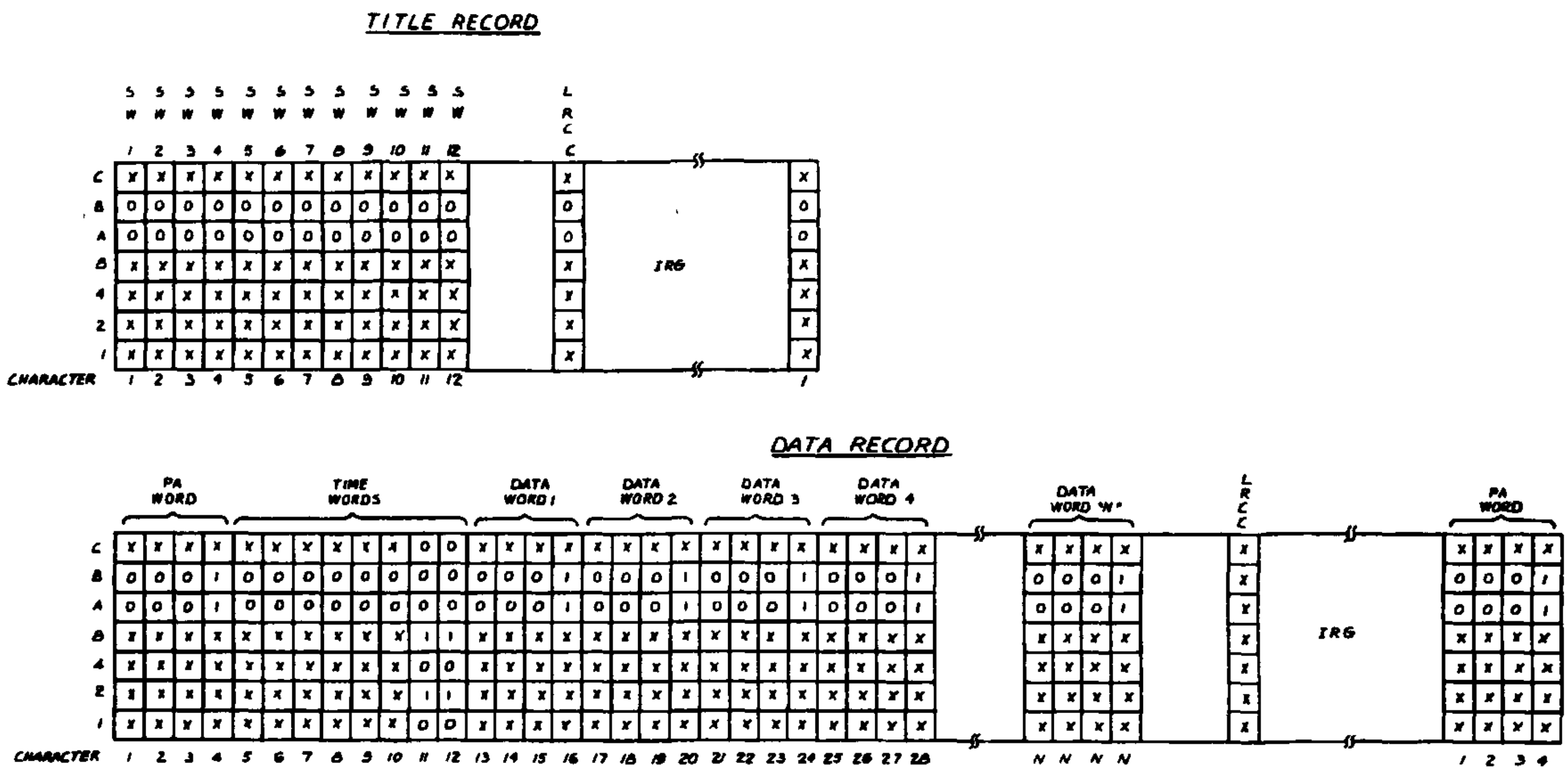
The amplifiers are IBM compatible and are designed to operate with a modified non-return to zero recording system at the maximum tape speed of the transport and with packing densities of 556 bits per inch. Any compensation required is built into the amplifiers.

D. Tape Format

All of the digital information produced by the system must be organized in a special, fixed manner, or format, for recording on magnetic tape. This format was determined for compatibility with the input requirements of an IBM 1401 computer available for use in BRL. Figure 8 shows this tape format, the top section indicating a title record and the bottom section indicating a data record.

The data in digital form appear either as the presence of a pulse indicating a binary "one" or the absence of a pulse indicating a binary "zero". These binary digits, or bits, are produced simultaneously on the seven-track tape recorder write head stack and are recorded laterally across the 1/2-inch width of tape. One row of such data is indicated as a character. The first four bits in a character contain the numerical information generated in the system representing one decimal digit. Bits in the A and B tracks respectively identify the least significant character in a data word and identify the sign of the word. The C track contains bits required for the "even" parity check of the system.

The title record consists of 12 characters of data inserted into the system by the front panel title switches, at one character per switch position. A three-character gap in the tape (determined by the timing logic in the system) then is generated and this is followed by a single character labelled LRCC which is a longitudinal check character for further parity checking. An inter-record gap 3/4 of an inch in tape length is then generated to complete the title record. When the system is operating in the data modes the tape format consists of a four-character word containing performance analyzer data, followed by six characters of timing data, and then two "pad" characters. Each word in the format must contain four characters, or groups of four characters, (modulo 4) and the pad



CHARACTER,

1 PA MSD
2 PA 3SD
3 PA 2SD
4 PA LSD
5 TENS SECONDS
6 UNITS SECONDS
7 TENTHS SECONDS
8 HUNDREDTHS SECONDS
9 MILLI SECONDS
10 TENTHS MILLISECONDS
11 PAD 0
12 PAD 0

FIG. 8 - MAGNETIC TAPE DATA FORMAT

characters are added to fulfill this requirement in the time word. Immediately following the last "pad" character are the characters forming the data words, derived from the input signals. The number of these data words is dependent upon the number of input channels in use and can be from one to 150 four-character words. After the last data word in a record an LRCC character and inter-record gap are written before another successive data record is begun.

When data runs are completed, an end-of-file gap 3 1/2 inches long is made on the tape followed by an end-of-file character, a 3 character gap, an LRCC character, and a 3/4-inch inter-record gap. The end-of-file character in this group is composed of a bit in the first four tracks. The end-of-file sequence is manually initiated by an operator from the system control panel. Two successive manual switch operations are normally used to identify the end-of-tape run.

In the generation of a data word on the tape, the first character represents the most significant digit and the fourth character represents the least significant digit of the recorded data.

E. Modes of Operation

The system is capable of operation in six on-line modes and three off-line modes. The on-line modes are those in which data from field located sensors are recorded on digital tape or read back from tape. In all the off-line modes, except for the calibration mode, the tape transport is not used. The system's input source in the three off-line modes is the output of the calibration power supply. Figure 9 shows the system control panel from which all these operational modes are controlled. The six on-line modes available are playback, write title, periodic scan, single scan, continuous scan, and end-of-file function. The three off-line modes are performance analyzer function in test-single position, performance analyzer function in test-all position, and calibration mode.

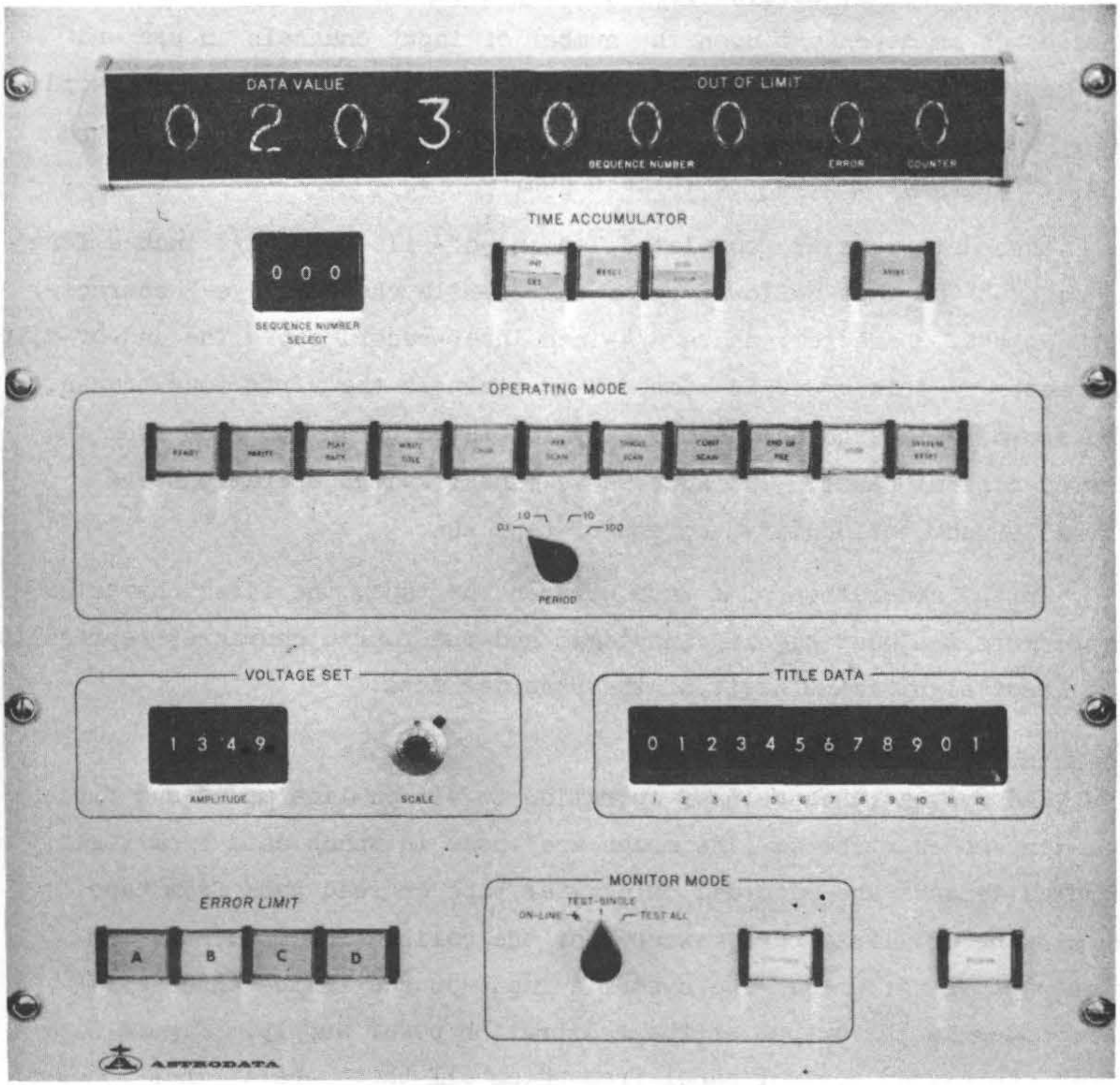


FIG. 9 - SYSTEM CONTROL PANEL

In the playback mode, pre-recorded data are read back from the digital tape and a specific data channel can be selected by switch operation for display on the Data Value indicator. The proposed addition of a digital-to-analog converter to the existing system will allow this selected channel to be recorded on an external chart recorder.

In the write title mode, the data selected by the 12 front panel switches are recorded on tape prior to a recording run. This includes such identification data as date, run number, test number and the like.

In the periodic scan mode, the system will completely scan all channels and record the data at intervals set by the front panel switch. These rates are 0.1 second, 1.0 second, 10 seconds and 100 seconds. The rate at which each sensor is sampled remains the same in each case, but the rate at which complete data scans are made varies according to the switch setting. The single scan mode allows for only one scan to be made and recorded; the continuous scan mode allows scanning to continue until manually stopped. The end-of-file mode allows the system operator to record the necessary data required by the tape format to identify the end-of-file.

In the performance analyzer test-single mode, calibration voltages adjusted by front panel controls are used as the system input. Any channel chosen by the sequence number selector switch is continuously displayed on the Data Value indicator and also compared with the input voltage. If the value of the selected channel exceeds limits set by error limit switches, the error counter displays the number of times the limit was exceeded.

In the performance analyzer test-all mode, no data are recorded on tape. System input is the calibration voltage and all channels are compared with the selected error limits. If any channel exceeds these limits, the system stops, the value of the channel is displayed on the Data Value display and the number of the channel in error is displayed on the sequence number indicator. Operation in these off-line modes allows one to quickly check overall functioning of the system, by determining if any channel is in error and by indicating which one it is.

In the calibration mode, the calibration voltage is again used as the system input and the system scans and records on tape all the channels in the system. This occurs only when the mode switch is in test-single position.

F. Printed Data Presentation

In checking the operation of the overall range data-gathering system including both the digital section and the field meteorological section, it is often desirable to have the data available in printed form before a large number of data runs is made. Figure 10 shows three types of printed data which have proven to be useful in such a system checkout.

The top two readouts were made with the IBM 1401 computer tabulating the data directly from the magnetic tape input. The top section shows the recorded voltage outputs for 15 channels when a known calibration voltage, noted in the far left column as PA, was used as the parallel input to all channels. From this type of presentation it can easily be determined if adjustments need to be made to the input amplifiers to meet the desired accuracy specifications.

The second section shows the various output voltages recorded on the 15 channels using input signals derived from field-located wind speed sensors. In this case the time data shows that successive scans of all channels were made at 0.1 second intervals. The voltage recorded under column DW 11 shows the results of a defective sensor and under column DW 15 the result of an open signal line.

The last section shows the final desired results obtained after the data were processed through a computer. The first print-out is the time of a specific scan followed by successive channels of wind speed in miles per hour. Directly below this, with the same time notation are the data for the wind direction in degrees. These data can also be obtained in a form which allows automatic plotting when desired.

01094110000l

PA	TIME	DW 1	DW02	DW03	DW04	DW05	DW06	DW07	DW08	DW09	DW10	DW11	DW12	DW13	DW14	DW15
2951	14.2060	2940	2958	2950	2952	2950	2998	2947	2944	2948	2947	2950	2949	2946	2948	2950
2953	15.8060	2942	2958	2950	2951	2950	2999	2948	2943	2949	2946	2949	2949	2943	2946	2949
2949	01.0030	2947	2956	2950	2955	2949	2997	2947	2946	2948	2945	2948	2950	2944	2949	2948
2951	02.0030	2946	2957	2949	2953	2949	2995	2946	2946	2949	2943	2948	2949	2944	2947	2947
2951	03.0030	2946	2956	2949	2953	2949	2998	2946	2946	2948	2946	2948	2948	2943	2948	2948

Calibration Voltages - Individual Channels

701 51.4011

PA	TIME	DW 1	DW02	DW03	DW04	DW05	DW06	DW07	DW08	DW09	DW10	DW11	DW12	DW13	DW14	DW15
2950	29.2030	2073	2100	1777	2444	2267	2187	2307	1580	2800	2355	880	2612	2770	2719	172
2950	29.3030	1791	2096	1625	2293	2090	2049	2462	1517	2848	2049	1077	2493	2525	2743	170
2950	29.4030	1694	2216	1714	2408	2170	2210	2199	1608	2743	2142	942	2512	2430	2913	170
2950	29.5030	1886	2248	1546	2340	2088	2213	2105	1719	2612	2115	[illegible]	2456	2294	2819	170
2950	29.6030	2161	2247	1730	2440	2079	2112	2190	1808	2423	2151	[illegible]	2702	2634	2917	[illegible]
2950	29.7030	2007	2419	1566	2342	2259	2199	2293	1740	2500	2253	[illegible]	2506	2271	2957	[illegible]
2949	29.8030	2094	2305	1450	2199	2112	2155	2280	1707	2324	2150	[illegible]	2453	2555	3014	[illegible]
2950	29.9030	2031	2197	1507	2298	2090	2209	2265	1619	2465	2112	[illegible]	2481	2312	2942	[illegible]
2949	30.0030	2331	2101	1344	2118	2035	2140	2108	1515	2504	2110	[illegible]	2457	2209	3089	[illegible]
2949	30.1030	2086	2114	1528	2207	2070	1946	2043	1609	2437	2080	[illegible]	2459	2421	3242	[illegible]
2950	30.2030	2032	2209	1363	2105	1914	2108	2158	1758	2297	2090	[illegible]	2590	2445	3248	[illegible]
2950	30.3030	2103	2156	1331	1982	2228	2157	1933	1801	2425	2112	[illegible]	2457	2510	3082	172
2950	30.4030	2151	2250	1266	2245	2064	2208	1850	1684	2386	2100	1179	2259	2386	2999	168
2951	30.5030	2090	2254	1339	2096	2034	2102	1979	1795	2518	2108	1411	2056	2293	2941	172
2950	30.6030	2337	2257	1379	2109	2102	2146	1831	1683	2314	2148	1902	2053	2324	2802	170
2949	30.7030	2177	2298	1316	2114	2003	2151	1989	1685	2423	2044	1735	2212	2485	3054	172

defective sensor

open channel

SCALE 12 MPH 9 SEPT.64 RUN NO. 6

Output Voltages - Wind Speed Sensor

```
30.1000 6.945 5.902 4.502 4.713 6.330 5.676 5.723 5.892 5.979 5.437 4.597   WS
4.248 4.552 3.056                                                            WS
30.1000 230.1 213.9 192.7 209.2 237.8 264.1 263.0 249.6 224.9 246.0 258.1   WD
224.5 222.5 247.3                                                            WD

30.2000 6.854 5.611 4.300 4.265 6.271 5.500 5.634 6.140 5.665 5.408 4.386   WS
3.970 3.896 3.128                                                            WS
30.2000 231.8 216.2 192.1 211.6 236.8 263.8 263.1 254.4 224.7 249.2 258.3   WD
225.6 221.6 247.3                                                            WD

30.3000 6.052 6.101 3.725 4.701 6.968 6.145 5.437 6.302 5.712 5.439 4.241   WS
4.222 4.101 3.481                                                            WS
30.3000 231.2 220.9 191.7 217.3 236.2 266.4 266.4 256.3 224.7 253.6 258.7   WD
228.5 222.0 246.0                                                            WD

30.4000 5.963 5.770 3.954 4.462 6.931 5.667 5.498 6.612 5.660 5.672 4.980   WS
4.485 3.973 3.128                                                            WS
30.4000 228.8 224.0 192.0 224.8 237.3 267.6 272.4 256.7 224.6 256.7 260.2   WD
230.5 222.0 246.2                                                            WD

30.5000 5.864 5.651 4.338 4.338 6.556 6.075 5.892 6.337 5.895 5.965 4.528   WS
4.831 3.680 3.030                                                            WS
30.5000 225.2 227.5 192.5 232.1 241.3 268.9 278.4 253.6 224.8 256.7 261.0   WD
225.6 222.0 246.6                                                            WD

30.6000 5.993 5.425 4.163 4.965 6.304 5.866 6.187 5.770 5.575 5.521 4.698   WS
4.906 4.022 3.512                                                            WS
30.6000 221.6 232.4 192.2 241.8 244.9 268.1 282.1 249.8 224.8 253.6 261.1   WD
224.2 221.5 245.2                                                            WD

30.7000 5.690 6.126 4.549 4.495 6.759 5.848 5.991 5.735 5.965 5.277 4.542   WS
4.698 4.070 3.618                                                            WS
30.7000 218.5 233.1 190.9 250.1 248.8 270.5 284.0 242.9 225.1 250.3 262.3   WD
220.8 220.5 242.5                                                            WD

30.8000 5.566 6.239 4.355 4.800 6.306 5.281 5.780 5.730 6.239 5.869 4.906   WS
4.705 3.620 3.222                                                            WS
30.8000 216.5 232.6 189.7 257.2 253.3 271.1 283.4 235.2 226.1 246.6 263.1   WD
217.2 220.7 242.0                                                            WD

30.9000 5.505 5.841 4.296 4.965 6.563 5.526 5.782 5.766 6.290 5.845 4.144   WS
4.904 4.360 3.507                                                            WS
30.9000 215.0 228.1 188.1 260.3 254.6 271.2 280.8 234.8 226.2 242.1 263.3   WD
213.7 221.7 241.9                                                            WD

31.0000 5.688 5.906 4.457 5.065 6.437 5.660 5.180 5.895 5.951 5.770 4.405   WS
4.651 3.744 3.863                                                            WS
31.0000 214.4 225.3 187.4 260.1 254.4 271.0 278.3 235.0 225.6 239.1 264.2   WD
211.1 221.4 243.1                                                            WD
```

Computer Print-out

FIG. 10 - PRINTED DATA PRESENTATION

IV. SENSORS

Meteorological measurements made to date utilizing the data acquisition system at the EMP range facility have been wind speed, wind direction (both azimuth and elevation), temperature and humidity. The types of sensors used to obtain these measurements have been as follows:

Wind Speed and Direction: AN/GMQ-12; Meteorology Research, Inc., Vector Vane 1053; and Beckman and Whitley Series 50.

Temperature: Honeywell Model 921A3 and Beckman and Whitley Model 60.1.

Humidity: Bendix Model DHGF-1P.

A. Wind Speed and Direction

1. The AN/GMQ-12 set consists of a wind speed sensor and a wind direction sensor with each feeding its own conversion and amplifying circuit. The speed sensor operates using a light chopper technique where the rotation of a cup anemometer causes the chopper to interrupt a light beam to a phototube. The wind speed determines the rate of interruption of the light beam and the phototube produces a resulting pulse output. This is converted to a varying DC voltage which is amplified and fed to the data acquisition system.

The wind vane of the direction sensor is mechanically coupled to the arm of a variable resistor. The position of this arm, determined by the wind direction, results in a DC voltage applied to an amplifier and thence to the data acquisition system.

The two sensors are attached to a cross-arm which can be mounted on a 6-foot tripod or on any of the tower positions. The associated amplifier and power supply unit for each type of sensor is located in an instrument shelter near each tower site. The output signals are then connected through a junction box to the instrument van for digitizing and recording.

2. The Model 1053 Vector Vane includes in a single unit the provision for measuring the wind speed and two components of wind direction, the elevation and azimuth. Figure 3 shows a unit mounted at the middle level on a sensor tower. It has the advantage over the type AN/GMQ-12 in accuracy, faster response time, and lower threshold characteristics. The fast response is achieved through improved aerodynamic and mechanical designs which minimize the mass of the responsive surfaces and friction in rotating parts. The directional response is carefully matched to the speed response so that, with allowance for the small physical separation of the sensing surfaces, both outputs describe the same wind change, or gust. Because of its light weight, care must be exercised in handling and mounting the unit.

The tail fins are light plastic with a thin aluminum protective covering. The windmill-propeller, used in place of cup anemometers, has four light magnesium blades. Aluminum tubing is used in various other parts. The vane can swing horizontally through a full circle and can pivot on the upright shaft. Vertically it can deflect ± 60° turning the shaft of a potentiometer located in the housing directly above the upright shaft. This provides a resistance change proportional to elevation angle. A miniaturized photocell and light source unit is also mounted in the housing. A light beam chopper directly attached to the propeller generates the output which is linearly related to wind speed.

The tube extending from the base houses the pivot shaft which operates a potentiometer under the cover at the base to produce a resistance change proportional to the azimuth angle of the vane. All sensor signals pass through a low-drag slip ring and brush assembly to an output connector.

Each Vector Vane requires an associated unit to furnish the necessary power and three separate electronic modules, one for each of the vane outputs. The modules contain the solid-state signal-conditioning circuits for each type of signal and produce an output both on a meter and at receptacles for connecting to the data acquistion

system. Provision is made in each module for obtaining full scale calibration voltages and for range and linearity adjustments. Figure 11 shows the Vector Vane and its associated equipment. Characteristics are listed in Table AI of the Appendix.

3. The Beckman and Whitley Series 50 wind measuring system incorporates several improvements over other systems used on the range. The use of air-gap capacitive transducers to sense the anemometer shaft rotation and vane position without contact or friction greatly reduces mechanical wear inherent in directly-coupled units using potentiometers or servos.

The speed sensor consists of a staggered six-cup anemometer, which rotates on low torque ball bearings and moves a capacitor rotor. This produces an amplitude modulated signal which is demodulated to provide a sinusoidal output voltage, the frequency of which is 40 times that of the shaft rotation. All of the necessary circuitry is mounted in the housing supporting the anemometer and is encapsulated in potting compound to improve reliability.

The direction sensor consists of a wind vane which can rotate freely on low torque bearings. As the wind direction changes the vane moves and the shaft turns causing a capacitor rotor to move. This phase shifts a 1 kc/s sinusoidal signal relative to a 1 kc/s reference signal by an amount directly proportional to the wind direction azimuth. Measurement of this phase shift produces the desired output. The circuitry for this is also mounted and encapsulated in a housing supporting the wind vane.

The output signals from the wind speed sensor are converted to constant volt-second pulses whose average dc value is directly proportional to wind speed. This output is coupled to the data acquisition system through suitable RC-filter networks. The signals from the wind direction sensor are converted to pulse widths which are directly proportional to wind direction. This output is also coupled to the data acquisition system through RC-filters. Since the Series 50 system

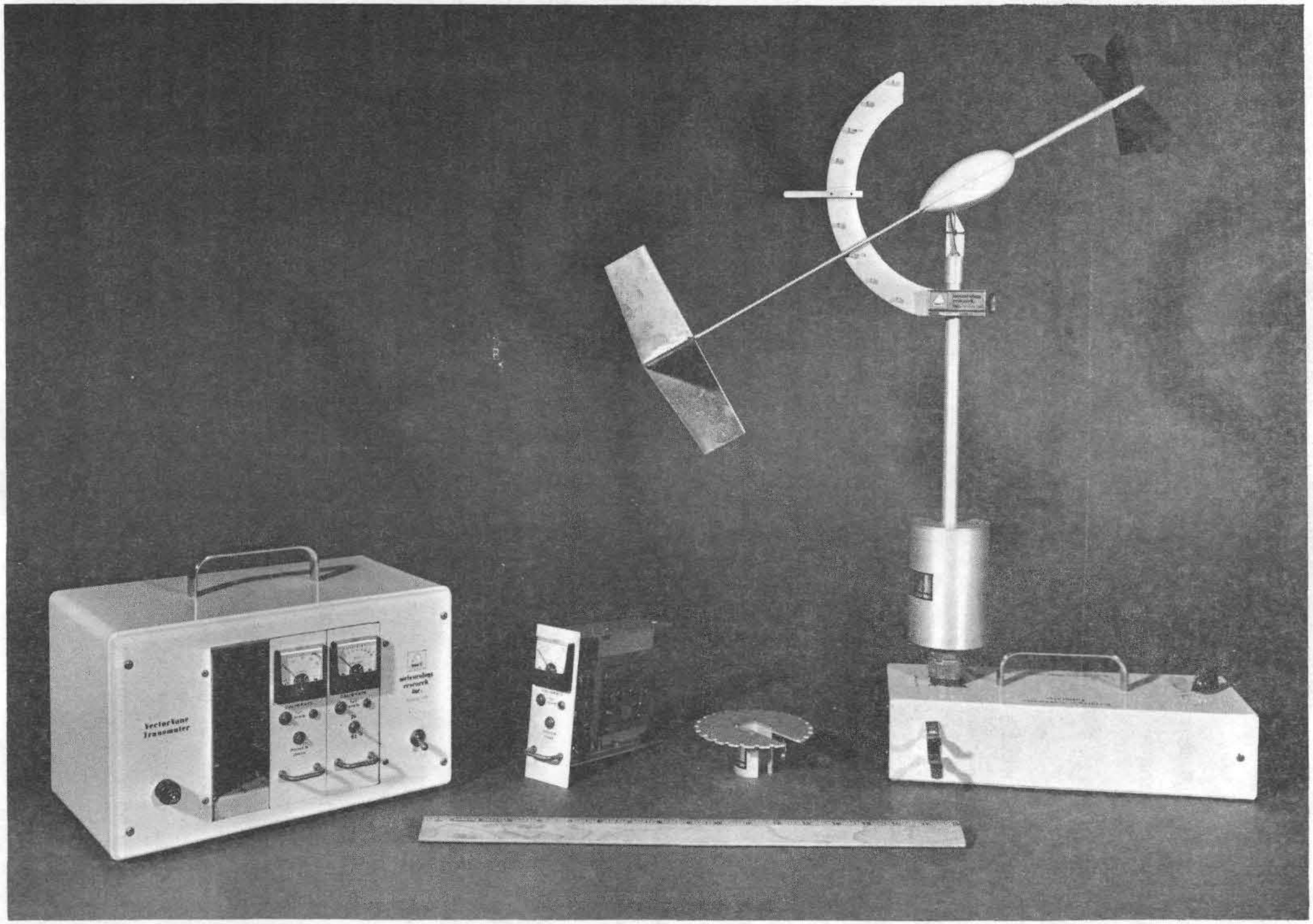


FIG. 11 - THE M.R.I. VECTOR VANE WITH AMPLIFIERS AND CALIBRATION JIGS

produces outputs which are frequencies instead of dc voltages, these signals can be transmitted up to 10 miles before insertion into the translators and thence to a data recording system. For range applications it is more desirable to have the translators directly at each field, or sensor site.

The direction sensor and speed sensor are each mounted on one end of a cross-arm of aluminum to allow either tripod or tower mounting. A special fixture is available for initial alignment of the direction sensor, and for replacement of sensors without realigment. Figure 12 shows the Series 50 wind measuring set. Characteristics are listed in Table AII of the Appendix .

B. Temperature

The measuring system used to obtain temperature data is the Beckman and Whitley Model 140 which consists of 18 resistance type sensors, an individual resistance bridge for each sensor, bridge power supplies, amplifiers, and a test circuit. Both the Beckman and Whitley Model 60.1 sensor and the Honeywell Model 921A3 sensor, individually mounted in a Model M327 aspirated thermal radiation shield, have been used. The sensor is connected as one side of a resistance bridge in a manner such that variations in sensor resistance due to temperature changes produce a bridge output voltage. This is amplified and fed to the data acquisition system for recording.

The sensor element is supported by a terminal board in the upper neck of the shield assembly. A co-axial internal shield with an absorption spectrum different from the radiation spectrum of the outer shield reduces the exchange of heat by re-radiation to the sensing element. The heat is given up to the air stream and extracted from the assembly by a squirrel-cage blower. Additional reflectors surrounding the upper and lower sensor regions are provided by the radiation shield. This type of shield is shown in Figure 13.

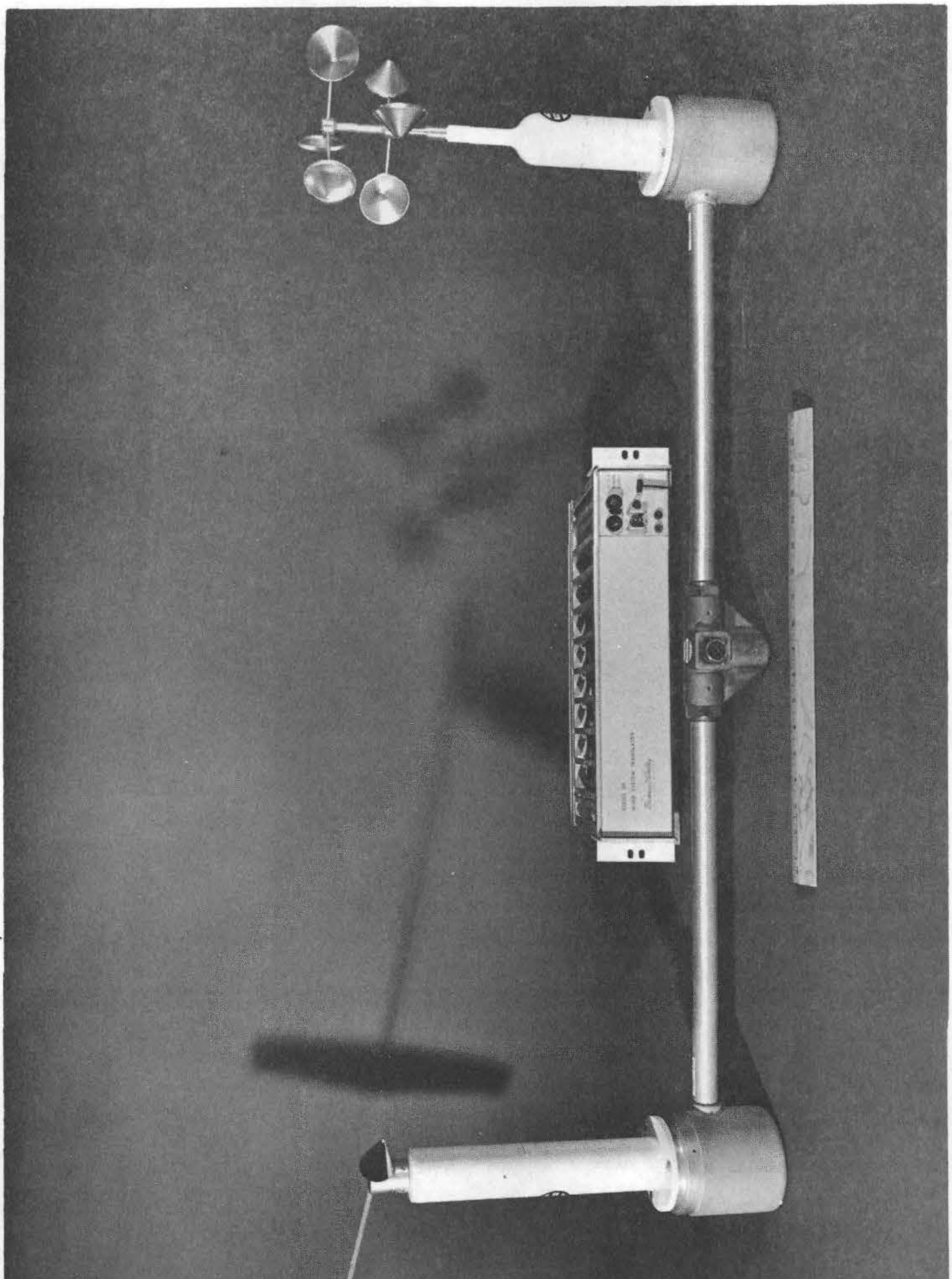


FIG. 12 - THE B. & W. SERIES 50 WIND MEASURING SYSTEM

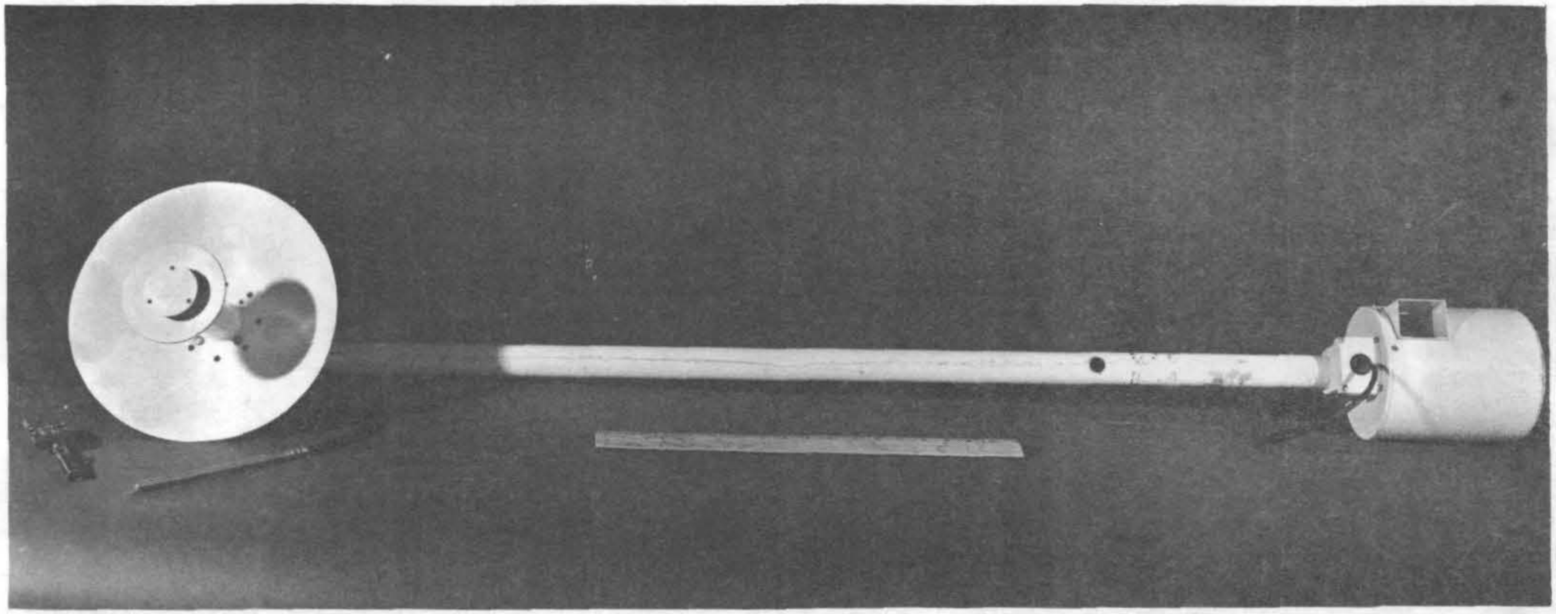


FIG. 13 - THERMAL RADIATION SHIELD AND TEMPERATURE SENSORS

The shielded sensors are connected to their respective bridge circuits through the long signal lines; two pairs of wires are needed for each sensor. Each bridge is independently powered by its own supply and all its resistors are contained in a single plug-in unit. The bridges are rack mounted in groups of ten per chassis and these are located in relay racks to the right of the data acquisition system in the instrument van. The resistors in each bridge are tailored for use with specific lead wire resistances from the tower sites and are not interchangeable. Each bridge contains two trim potentiometers for span and zero adjustment when in use with the sensors at specific sites.

The bridge uses a Kelvin double bridge modification of the conventional Wheatsone bridge to increase accuracy by suppressing errors due to variations in lead wire resistance. The bridge operates from a well-regulated 10 volt dc source furnishing excitation current of 0.8 milliamperes to the sensor. The voltage output of the bridge varies from 0 volts at $-40^{\circ}F$ to 0.05 volts at $+140^{\circ}F$ as shown below. This output is amplified by a solid-state operational amplifier, Fairchild Model A00-6, with a fixed gain of 100: this permits a 0 to 5.0 volt output to be fed to the data acquisition system. The test circuit consists of a Zener regulated divider network, a switching arrangement, and front panel meter to allow the checking and metering of each bridge amplifier.

The following table shows the relationship of temperature, sensor resistance, and bridge output voltage obtained with the measuring system.

Temperature (°F)	Bridge Output (Volts)	Sensor Resistance (ohms)
-40	.000000	417.3
-30	.002749	429.4
-20	.005492	441.6
-10	.008229	453.9
0	.010982	466.4
+10	.013728	479.0
20	.016489	491.8
30	.019285	504.9
40	.022071	518.1
50	.024870	531.5
60	.027659	545.0
70	.030438	558 6
80	.033208	572.3
90	.035987	586.2
100	.038755	600.2
110	.041551	614.5
120	.044355	629.0
130	.047165	643.7
140	.050000	658.7

The Beckman and Whitley Model 60.1 sensor is a manganin-nickel wire resistance thermometer element constructed to provide maximum performance in the radiation shield. The wire is wound on the outside of a thin metal, hollow cylinder approximately 2 inches long attached to a mounting strip to allow insertion into the radiation shield. This type of construction was used to obtain a fast response which produced a time constant of 0.35 seconds in stirred oil. Experience with these sensors in the field indicates that they are extremely fragile and the resistance wire tends to break unless extreme caution in handling is used. Several of the units showed a break in the wire after they had been properly placed in the shields and initially checked. Further design effort must be spent to provide a practical field sensor of this type if fast response is required. The second type of temperature sensor used was the Honeywell Model 921A3 nickel resistance thermometer bulb, with the winding encased in a stainless steel outer shell. It has the same temperature-resistance characteristics as the Model 60.1 and can be directly substituted for it in the bridge system. This sensor was adapted for mounting in the same radiation shield as the Model 60.1

sensor. It has proved to be rugged enough for field use but its time constant is several times greater than that of the Model 60.1 and its use is limited to measurements where this factor is not important.

C. Humidity

Measurements of humidity have been made on the range using the Bendix Corporation's Model DHGF-1P dewpoint hygrometer. In this instrument the dewpoint temperature is determined by passing an electric current of sufficient magnitude through a Peltier junction to form a thin layer of frost on a silver mirror surface. The temperature must be controlled so that the thin layer of frost is maintained at approximately a constant thickness. With the condition of unchanging thickness, the saturated water vapor pressure over the mirror film is equal to the partial pressure of water vapor in the air sample. Then the mirror surface temperature is the dewpoint of the air sample.

Two methods of detection of this layer of frost are used, the first one monitors the thickness by a photocell focussed on the mirror surface, controlling, through a servo amplifier, the current to the Peltier junction, the second method uses a thermistor imbedded in the mirror to monitor the temperature of the mirror required to maintain the frost thickness at equilibrum. A signal conditioning amplifier converts the thermistor output to a useful voltage output.

The instrument includes two units, one the power supply and the other the sensing, or hygrometer section. Both are shown in Figure 14. Attached to the sensing section is a passivated stainless steel inlet tube which allows air samples to be brought to the mirror position without changing the sample's moisture content. The servo amplifier and control circuitry are also included in this unit.

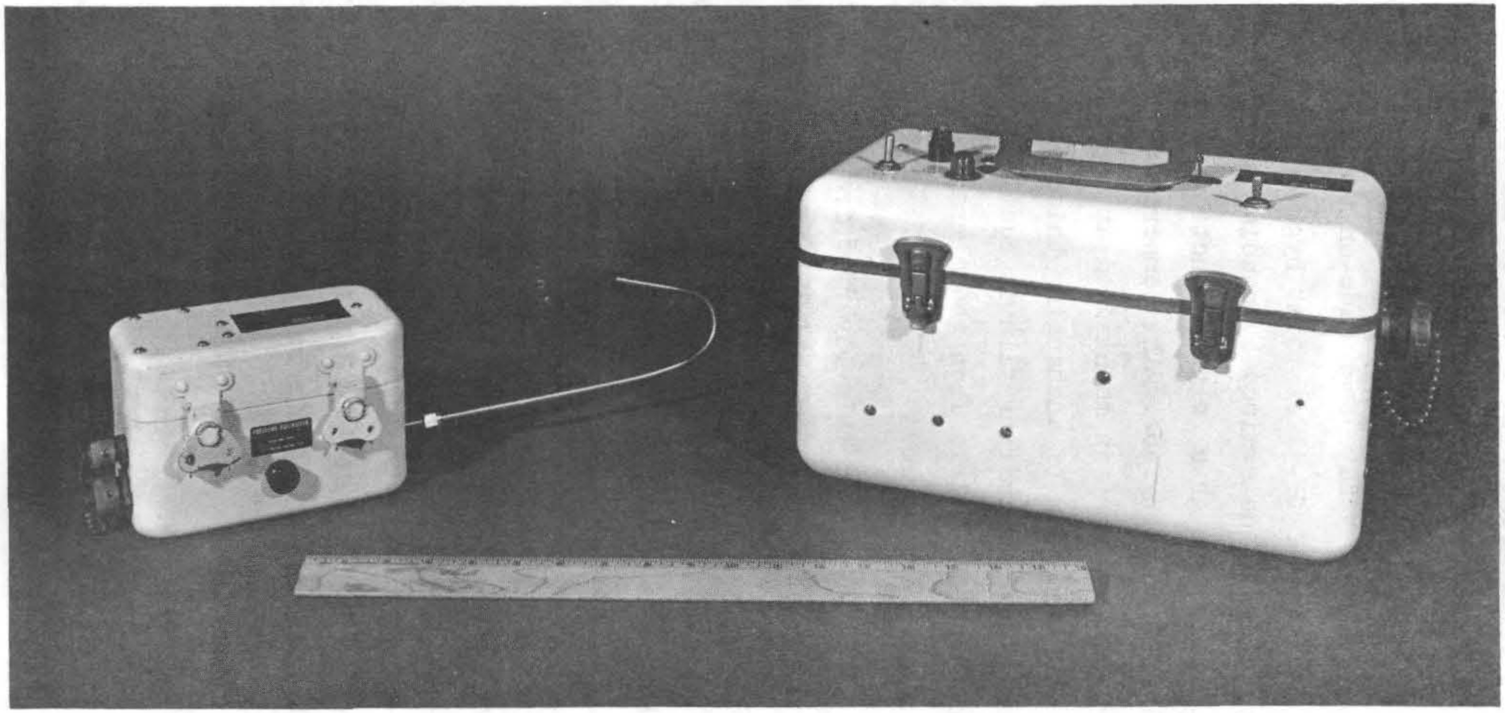


FIG. 14 - THE BENDIX MODEL DHGF-1P DEWPOINT HYGROMETER

V. CALIBRATION METHODS

Since the data acquisition system operates with analog input signals over the range of 0 to ± 5 volts, it is necessary to convert the phenomenon being measured to a voltage. The calibration of the measuring device, or sensor, becomes most important if meaningful measurements are to be obtained. Facilities for producing, controlling, and measuring the environment over the desired operating range for the calibration of all types of sensors used in field measurements are desired but are not always available. In lieu of this direction calibration, the data furnished by the manufacturer must be relied upon.

Experience on the EMP range with a large number of various types of sensors indicates that sensor calibration is a major part of any field measurement program. Once this has been carefully completed, the actual data gathering process is very fast because of the high speed of the data acquisition system.

A. Wind Speed Sensor Calibration

Two methods have been used for the calibration of wind speed sensors, one utilizing the facilities of the BRL wind tunnel and the other a more direct, but less precise field calibration.

1. Wind Tunnel Calibration. Three types of wind speed sensors, or anemometers, were available for calibration in the BRL wind tunnel. These included two units of Type AN/GMQ-12, three units of the M.R.I. Vector Vane 1053, and one unit of Climet Model 011-1. A single sensor at a time was attached to a suitable mount which was placed in the air stream in the 93-inch section of the supply header piping of Tunnel Number 3. By setting the nozzle throat, controlled air velocities were generated over the range of approximately 1 to 19 miles per hour and were accurate to ± 5 percent. Circuitry associated with the sensor produced an output signal with a frequency proportional to wind speed. This frequency was measured on a counter and printed out with a digital printer every two seconds for the duration of a run. The air stream was allowed to stabilize at each desired speed and then data were obtained for several minutes on each run. A large

number of data points was thus obtained for each sensor at each speed over the entire speed range. Table I shows the data summary of these wind tunnel calibrations. The summary indicates lower standard deviations in the measurements made using the Vector Vane than from the other two types of sensors. The standard deviations are approximately the same for the AN/GMQ-12 and Climet Model 011-1. This was predictable since both types are quite similar in design and use anemometer cups as the sensing device. The Vector Vane uses a sharply pitched propeller in place of the anemometer cups. This appears to improve the consistency of measurement over the range of calibrated wind speeds. A second run was made on one unit of the AN/GMQ-12 and the data summary shows reasonable agreement with the first run.

From these data the best straight line equation was calculated and plotted for each sensor calibrated. Figure 15 shows the results for a typical sensor of each type calibrated in the wind tunnel.

Before the system can be used in the field, one must know the relation between the frequency of the output signal (produced by the air speed on the sensing device) and the analog output voltage must be available. Usually the manufacturer furnishes data which relates the air speed and the output frequency for a specific type of sensor. As an example, the calibration of an anemometer cup unit used with the AN/GMQ-12 unit was as follows:

$$S \text{ (in mph)} = 0.637 + \frac{\text{Frequency (in cps)}}{29.547}$$

Thus, a known output frequency equivalent to a specific input air speed on the sensing device could be determined. Then a suitable signal of this frequency could be fed into the associated amplifier circuits and the output voltages measured. Figure 16 shows a graph of input frequency versus output voltage for various scale settings of an AN/GMQ-12 amplifier.

Table I

Data Summary, BRL Wind Tunnel Tests

SENSOR: M.R.I. VECTOR VANE (20 SLOTS)

Air Velocity Ft./Sec.	Air Velocity Mi/Hr.	Serial 160 Data Points	Serial 160 Frequency Output (Mean)	Serial 160 Std. Dev.	Serial 162 Data Points	Serial 162 Frequency Output (Mean)	Serial 162 Std. Dev.	Serial 163 Data Points	Serial 163 Frequency Output (Mean)	Serial 163 Std. Dev.
27.0	18.41	115	191	0.77	155	196	0.91	74	194	0.73
23.5	16.02	-	-	-	74	162	2.47	-	-	-
16.0	10.91	116	118	0.67	80	114	6.54	94	119	0.62
7.0	4.77	121	49	0.71	129	50	0.66	98	46	0.55
4.1	2.79	79	28	0.77	121	28	0.73	116	26	0.68
2.2	1.50	226	16	0.51	86	17	0.76	88	15	0.80
1.5	1.02	126	14	1.53	122	7	0.56	-	-	

SENSOR: AN/GMQ-12 (100 SLOTS)

Air Velocity Ft./Sec.	Air Velocity Mi/Hr.	Ser. 48 (Run 1) Data Points	Ser. 48 (Run 1) Frequency Output (Mean)	Ser. 48 (Run 1) Std. Dev.	Ser. 48 (Run 2) Data Points	Ser. 48 (Run 2) Frequency Output (Mean)	Ser. 48 (Run 2) Std. Dev.	Ser. 49 Data Points	Ser. 49 Frequency Output (Mean)	Ser. 49 Std. Dev.
27.0	18.41	77	582	4.25	142	542	5.19	57	602	4.66
23.5	16.02	-	-	-	-	-	-	56	514	5.26
16.0	10.91	94	349	5.59	119	329	4.24	85	365	4.25
7.0	4.77	131	140	2.27	164	133	2.35	-	-	-
4.1	2.79	141	76	1.76	74	74	1.56	-	-	-
2.2	1.50	182	43	2.18	106	37	2.42	-	-	-
1.5	1.02	96	19	3.09	-	-	-	-	-	-
1.5	1.02	50	17	3.18	-	-	-	-	-	-

SENSOR: CLIMET-MODEL 011-1 (100 SLOTS)

Air Velocity Ft./Sec.	Air Velocity Mi/Hr.	Ser. 173 Data Points	Ser. 173 Frequency Output (Mean)	Ser. 173 Std. Dev.
27.0	18.41	86	605	4.64
23.5	16.02	119	499	6.16
16.0	10.91	67	364	4.17
7.0	4.77	47	149	2.18
4.1	2.79	102	82	1.55
2.2	1.50	85	45	0.98
1.5	1.02	103	18	1.06

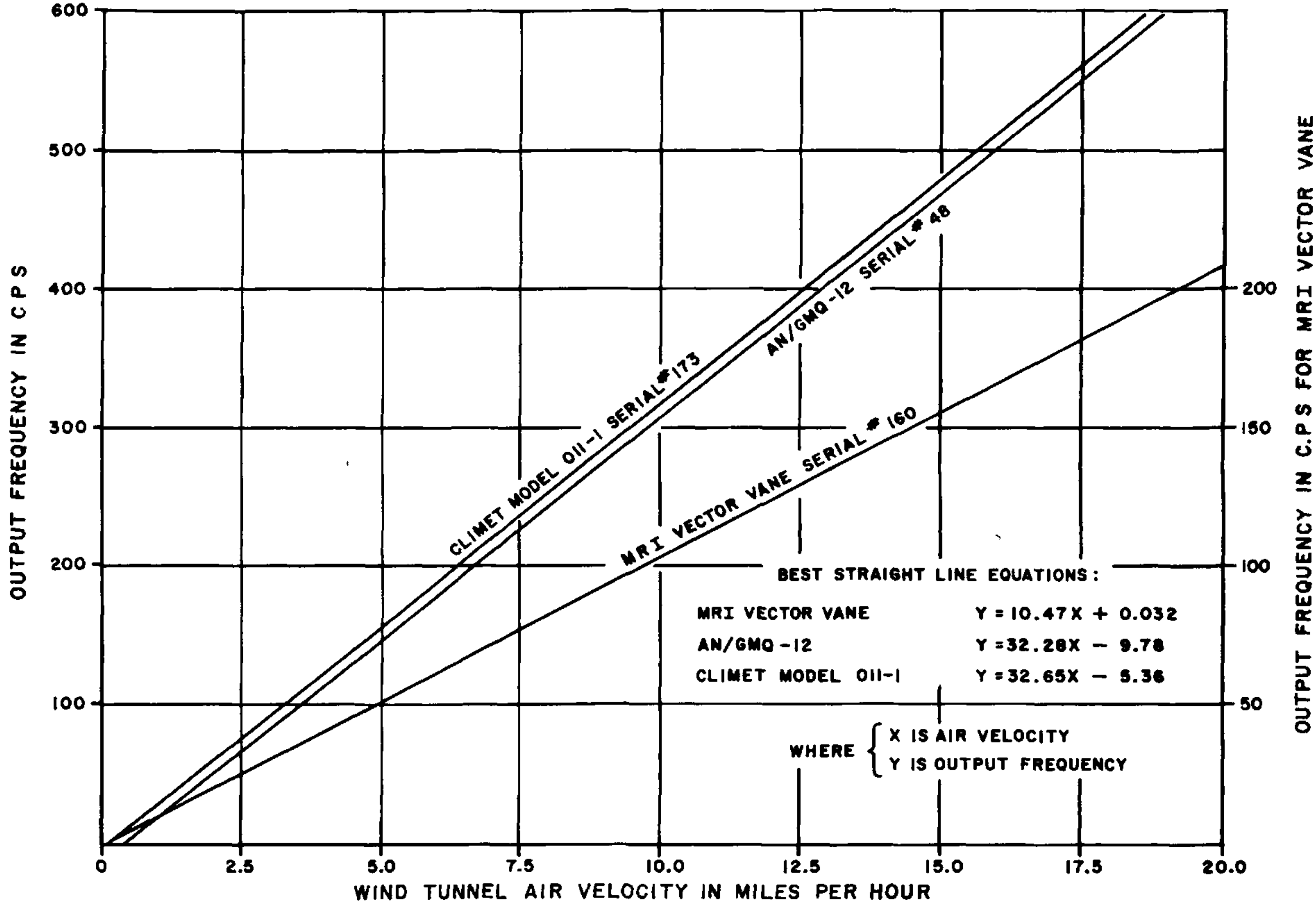


FIG. 15 WIND TUNNEL CALIBRATION OF WIND SPEED SENSORS

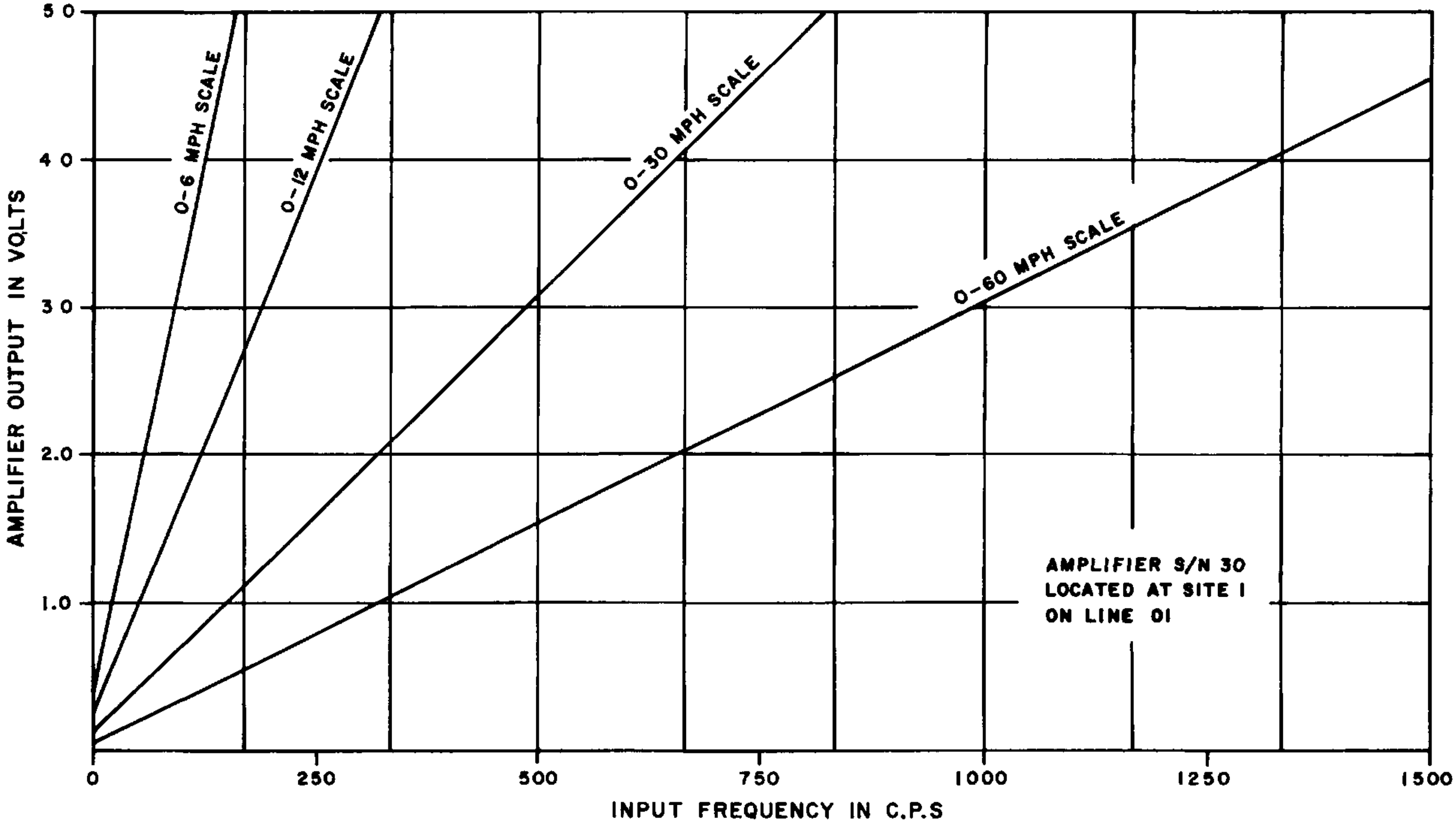


FIG. 16 FREQUENCY VS VOLTAGE FOR AN/GMQ-12 AMPLIFIER

2. <u>Field Calibration</u>. It soon became evident that it was not practical to calibrate each wind speed sensor in the wind tunnel for every program, especially since some programs required the use of many sensors. To simulate specific air velocities it was necessary to use a method suitable for quick, accurate calibration of sensors installed at their various field positions. A group of synchronous motors, each geared down to a desired shaft speed and covering an equivalent range of wind speed from 3 to 21 mph was obtained. The powered shafts of these units were temporarily attached to the shafts of the sensors through a rubber bushing or coupling. The sensor shaft thus rotating at a known speed produced a voltage at the system output. It should be noted that the same group of motor drive units did not serve to calibrate all of the types of wind speed sensors presently available. This was due to the differences in the number of slots in the light chopper discs of sensors of various manufacturers. However, a total of six units was adequate to calibrate all available sensors. In calibrating the Vector Vane 1053 wind speed sensor, it was necessary to account for the propeller pitch in determining the equivalent wind speed for a specific motor drive unit.

The first field calibrations using the simple method were made with the sensors in place at various positions as noted. Operating personnel were elevated to the sensor positions with the use of a "cherry-picker" lift vehicle. The motor drive units were then coupled to the sensor shafts and a complete calibration was made through the whole system, including amplifiers and long interconnecting lines to the data acquisition van. The output voltages were measured on digital voltmeters and recorded. Table II is a summary of this field calibration. From these measurements the best straight line equation was obtained for each field calibrated sensor. These are included in Table III and have served as the sensor calibrations for most field programs. At a later date, two units of a new type of wind speed and direction system designated as the Beckman and Whitley Series 50, were obtained. Similar calibrations were made on this model and the results, including the best straight line equations, are listed in Tables IV and V.

Table II

Field Calibration, Wind Speed Sensors

SENSOR SERIAL NUMBER	FIELD SITE	TOWER LEVEL	SENSOR TYPE	DRIVE MOTOR SHAFT SPEED IN rps				
				1.2	1.67	3.0	5.0	6.0
				(1) EQUIVALENT WIND SPEED IN MPH				
				4.69	6.28	10.78	17.55	20.93
				(2) MEASURED OUTPUT VOLTAGES				
5	1	bottom	AN/GMQ-12	0.840	1.136	1.914	3.091	3.702
56	1	top	AN/GMQ-12	0.898	1.214	2.124	3.297	3.976
15	2	bottom	AN/GMQ-12	0.834	1.123	1.926	3.110	3.692
47	2	top	AN/GMQ-12	0.887	1.219	2.001	3.278	3.888
63	3	bottom	AN/GMQ-12	0.870	1.160	1.992	3.218	3.795
21	3	top	AN/GMQ-12	0.867	1.150	1.956	3.186	3.783
45	4	bottom	AN/GMQ-12	0.862	1.138	1.970	3.178	3.778
57	4	top	AN/GMQ-12	0.852	1.158	2.014	3.236	3.854
49	5	bottom	AN/GMQ-12	0.871	1.167	2.006	3.199	3.840
59	5	top	AN/GMQ-12	0.879	1.168	1.995	3.217	3.848
			MEAN	0.886	1.1633	1.9898	3.2010	3.8156
			STD DEV.	0.0275	0.0298	0.0551	0.0615	0.0807

(1) N.B.S. calibration used for calculation of velocity
(2) Measured at Van with DANA DVM Amplifier Scale 30 mph

SENSOR SERIAL NUMBER	FIELD SITE	TOWER LEVEL	SENSOR TYPE	DRIVE MOTOR SHAFT SPEED IN rps				
				1.67	3.0	5.0	6.0	10.0
				(1) EQUIVALENT WIND SPEED IN MPH				
				2.95	5.93	9.89	11.86	19.77
				(2) MEASURED OUTPUT VOLTAGES				
165	1	center	MRI VECTOR VANE	0.645	1.308	2.347	2.867	4.879
163	2	center	MRI VECTOR VANE	0.646	1.312	2.354	2.876	4.992
161	3	center	MRIVECTOR VANE	0.728	1.395	2.390	2.886	4.891
118	4	center	MRI VECTOR VANE	0.648	1.338	2.372	2.894	4.862
166	5	center	MRI VECTOR VANE	0.646	1.272	2.267	2.827	4.865
			MEAN	0.6626	1.325	2.346	2.870	4.8838
			STD DEV.	0.0326	0.0408	0.0422	0.0422	0.0217

Amplifier Scale Set At 20 mph
(1) Propeller pitch is 2.90 ft/rev. and Output frequency is 20 cps/rev
(2) Voltages measured at Data Van with DANA DVM

Table III

Calibration Data, Wind Speed Sensors

SENSOR TYPE	SERIAL NO.	TEST	BEST EQUATION OF STRAIGHT LINE
AN/GMQ-12	48 (Run 1)	Wind Tunnel	where X = wind velocity in mph & Y = output freq. in cps Y = 32.28X -9.78
AN/GMQ-12	48 (Run 2)	Wind Tunnel	Y = 30.11X -8.12
Climet, 011-1	173	Wind Tunnel	Y = 32.65X -5.36
MRI Vector Vane	160	Wind Tunnel	Y = 10.47X +0.032
MRI Vector Vane	162	Wind Tunnel	Y = 10.42X +0.025
MRI Vector Vane	163	Wind Tunnel	Y =10.78X -2.64
AN/GMQ-12		Mfr Calibration	Y = 29.25X -14.6

SENSOR TYPE	SERIAL NO.	TEST	BEST EQUATION OF STRAIGHT LINE where X = wind velocity in mph & Y = output voltage
AN/GMQ-12	49	Field Calib	Y = 0.182X +0.024
AN/GMQ-12	59	Field Calib	Y = 0.183X +0.017
AN/GMQ-12	5	Field Calib	Y = 0.175X +0.029
AN/GMQ-12	56	Field Calib	Y = 0.188X +0.037
AN/GMQ-12	15	Field Calib	Y = 0.176X +0.017
AN/GMQ-12	47	Field Calib	Y = 0.184X +0.038
AN/GMQ-12	63	Field Calib	Y = 0.181X +0.026
AN/GMQ-12	21	Field Calib	Y = 0.180X +0.020
AN/GMQ-12	45	Field Calib	Y = 0.180X +0.017
AN/GMQ-12	57	Field Calib	Y =0.184X +0.006
MRI Vector Vane	161	Field Calib	Y = 0.249X -0.052
MRI Vector Vane	118	Field Calib	Y = 0.252X -0.117
MRI Vector Vane	163	Field Calib	Y = 0.256X -0.158
MRI Vector Vane	165	Field Calib	Y = 0.254X -0.151
MRI Vector Vane	166	Field Calib	Y = 0.253X -0.175

Table IV

Calibration Data, B&W Series 50 Wind Measuring System

WIND SPEED		OUTPUT VOLTAGE - WITH #1 FILTER					
		TRANSLATOR #134			TRANSLATOR #138		
MILES PER HOUR	EQUIVALENT* FREQUENCY	30 M.P.H. SCALE	60 M.P.H. SCALE	90 M.P.H. SCALE	30 M.P.H. SCALE	60 M.P.H. SCALE	90 M.P.H. SCALE
0	0.00	0.02	0.015	0.01	0.02	0.015	0.01
5	51.68	0.17	0.08	0.06	0.17	0.10	0.07
10	110.78	0.34	0.18	0.11	0.35	0.17	0.12
20	228.97	0.69	0.34	0.22	0.70	0.36	0.24
30	347.16	1.04	0.53	0.36	1.05	0.52	0.35
40	465.35	1.38	0.70	0.47	1.39	0.71	0.48
50	583.54		0.88	0.59		0.88	0.59
60	701.73		1.04	0.70		1.05	0.71
70	819.92		1.22	0.82		1.22	0.82
80	938.11		1.38	0.93		1.39	0.95
90	1056.30			1.05			1.05
100	1174.49			1.16			1.16
110	1292.68			1.27			1.27
120	1410.87			1.38			1.38

*From mfr. where speed = 0.0846 x Frequency (in c.p.s.) + 0.627, for 40 slot sensor.

DIRECTION ⟶	0°	90°	180°	270°	360°
	OUTPUT VOLTAGES				
Transmitter 158, Translator 152	0.00	0.28	0.54	0.76	0.99
Transmitter 158, Translator 159	0.00	0 27	0.53	0.77	0.99
Transmitter 160, Translator 152	0.00	0 24	0.50	0 75	0.98
Transmitter 160, Translator 159	0.00	0.24	0.50	0.75	0.98

Table V

Field Calibration of Wind Speed Sensors Using Motor Drive

MOTOR GEAR RATIO	R.P.S.	AN/GMQ-12 (100 SLOTS) FREQ. IN C.P.S.	EQUIV. SPEED IN M.P.H. (1)	VOLTAGE OUTPUT (30 SCALE) (2)	M.R.I. VECTOR VANE (20 SLOTS) FREQ. IN C.P.S.	EQUIV. SPEED IN M.P.H. (3)	VOLTAGE OUTPUT (20 SCALE) (4)	B&W SERIES 50 (40 SLOTS) FREQ. IN C.P.S.	EQUIV. SPEED IN M.P.H. (5)	VOLTAGE OUTPUT (6) 90 SCALE	60 SCALE	30 SCALE
5:1	12	1200	41.24	-	240	23.73	-	480	41.24	0.481	0.722	1.443
6:1	10	1000	34.47	-	200	19.77	4.94	400	34.47	0.403	0.605	1.209
10:1	6	600	20.93	3.820	120	11.86	2.97	240	20.93	0.247	0.371	0.741
12:1	5	500	17.55	3.207	100	9.89	2.47	200	17.55	0.208	0.312	0.624
20:1	3	300	10.78	1.979	60	5.93	1.48	120	10.78	0.129	0.194	0.387
36:1	1.67	167	6.28	1.162	33.3	2.95	0.74	66.7	6.27	0.077	0.116	0.231
50:1	1.2	120	4.69	0.874	24	2.37	0.59	48	4.69	0.059	0.089	0.177
Best straight line equations, where y is the output voltage and x is the wind velocity in M.P.H.		30 scale: $y = 0.1814(x) + 0.023$			20 scale: $y = 0.2501(x) - .0004$ 80 scale: $y = .06255(x) - .0016$			90 scale: $y = .01154(x) + 0.005$ 60 scale: $y = .01731(x) + 0.008$ 30 scale: $y = .03462(x) + 0.015$				

NOTES: (1) From N.B.S. Calibration, where $x = 0.627 + \frac{\text{Frequency (in c.p.s.)}}{29.547}$

(2) From best straight line equation obtained by motor drive calibration on ten (10) sensors.
(3) Where propellor pitch is 2.90 feet/revolution.
(4) Values obtained from field data using motor drive, where 5.0 volt output = 20 M.P.H.
(5) From manufacturers data where $x = 0.627 + 0.0846\ x$ (Frequency).
(6) Values obtained from field data using motor drive calibration.

The calibration data indicate that the best method of wind speed calibration is the wind tunnel method since it yields the most consistent, repetitive results under controlled conditions. For most programs, however, the field calibration method will usually be adequate for the measurement accuracies desired. Calibration can be done by non-technical personnel after the sensors have been mounted in the field positions.

B. Wind Direction Calibration

Since the wind vane of the direction sensor is coupled directly to the center arm of a potentiometer, a dc voltage determined by vane position can be obtained. The important point to note is that the center position of the potentiometer's total range must represent the center of the voltage range. This reference point must also be known with respect to true compass position for the dc output voltages to have any direction significance during a field data run. This requires careful sensor installation at all field sites and the proper orientation of each direction sensor with a known compass position. At the EMP range, Magnetic West was chosen as this reference point, representing mid-scale in voltage and 180° in direction. Calibration was accomplished by shifting the vane position in known horizontal angular increments and recording the resultant voltage. To do this, a round, flat, metal plate, or jig, was obtained with notches cut on the outside circumference every five degrees. The jig was placed over the sensor housing in a manner that would allow the vane arm to be positioned into any notched position. After the center voltage position was obtained for the mechanical center position of the vane on the jig, the complete sensor and jig was oriented to the desired compass position and locked in place. Calibration was carried out in 45° increments. Figure 17 shows the jig in the calibrate position for a direction sensor at the top level of a sensor tower. Table VI is a summary of the field calibrations made in the above manner on ten AN/GMQ-12 direction sensors, and five Vector Vane 1053 sensors. It should be noted that the latter sensors could be calibrated both in azimuth and elevation. For the Vector Vane sensors, the same calibration techique was used but required jigs furnished by the manufacturer. The horizontal positions could be obtained in 15° increments over a 360° range and the vertical position in 15° increments both plus and minus 60° from the level position. Figure 18 shows the direction calibration for a Vector Vane 1053 sensor.

FIG. 17 - ON-SITE CALIBRATION OF WIND DIRECTION SENSOR USING JIG

Table VI

Field Calibration of Wind Direction Sensors

SENSOR TYPE	SENSOR SERIAL NUMBER	FIELD SITE	TOWER LEVEL	AZIMUTH EAST 0°/360°	S.E. 45°	SOUTH 90°	S.W. 135°	WEST 180°	N.W. 225°	NORTH 270°	N.E. 315°
				(1) Measured Output Voltages							
AN/GMQ-12	14	1	BOTTOM	4.973	0.708	1.312	1.915	2.510	3.110	3.724	4.358
AN/GMQ-12	11	1	TOP	4.731	0.714	1.342	1.924	2.574	3.192	3.821	4.444
AN/GMQ-12	44	2	BOTTOM	4.936	0.687	1.295	1.920	2.524	3.144	3.766	4.387
AN/GMQ-12	36	2	TOP	4.881	0.679	1.299	1.848	2.501	3.104	3.710	4.306
AN/GMQ-12	22	3	BOTTOM	4.911	0.575	1.244	1.880	2.493	3.093	3.699	4.302
AN/GMQ-12	7	3	TOP	4.936	0.684	1.326	1.931	2.520	3.037	3.680	4.303
AN/GMQ-12	30	4	BOTTOM	4.891	0.540	1.171	1.810	2.461	3.102	3.742	4.392
AN/GMQ-12	33	4	TOP	4.914	0.777	1.381	1.936	2.513	3.087	3.662	4.283
AN/GMQ-12	28	5	BOTTOM	4.954	0.639	1.286	1.891	2.474	3.058	3.673	4.315
AN/GMQ-12	10	5	TOP	4.962	0.642	1.263	1.887	2.528	3.151	3.784	4.466
			MEAN	4.9089	0.6645	1.2919	1.8992	2.5098	3.1078	3.7261	4.3556
			STD DEV	0.0656	0.0654	0.0546	0.0349	0.0296	0.0429	0.0492	0.0611
MRI VEC. VANE	165	1	CENTER	0.092	0.628	1.272	1.877	2.473	3.099	3.723	4.348
MRI	163	2	CENTER	0.081	0.699	1.321	1.931	2.533	3.154	3.779	4.403
MRI	161	3	CENTER	0.036	0.607	1.252	1.902	2.575	3.231	3.885	4.515
MRI	109	4	CENTER	0.023	0.568	1.197	1.811	2.444	3.081	3.711	4.301
MRI	113	5	CENTER	0.092	0.657	1.259	1.865	2.506	3.130	3.727	4.305
			MEAN	0.0648	0.6318	1.2602	1.8772	2.5062	3.139	3.765	4.3742
			STD DEV	0.0294	0.0444	0.0397	0.0401	0.0457	0.0178	0.0604	0.0793

SENSOR TYPE	SENSOR SERIAL NUMBER	FIELD SITE	TOWER LEVEL	ELEVATION +60°	0°	-60°
				(1) Measured Voltages		
MRI VEC. VANE	165	1	CENTER	4.799	2.469	0.026
MRI	163	2	CENTER	4.888	2.476	0.038
MRI	161	3	CENTER	4.880	2.380	0.023
MRI	109	4	CENTER	4.959	2.506	0.019
MRI	113	5	CENTER	4.952	2.495	0.030
			MEAN	4.8956	2.4652	0.0272
			STD DEV	0.058	0.0446	0.0145

(1) Measured at Data Van with Dana Digital Voltmeter

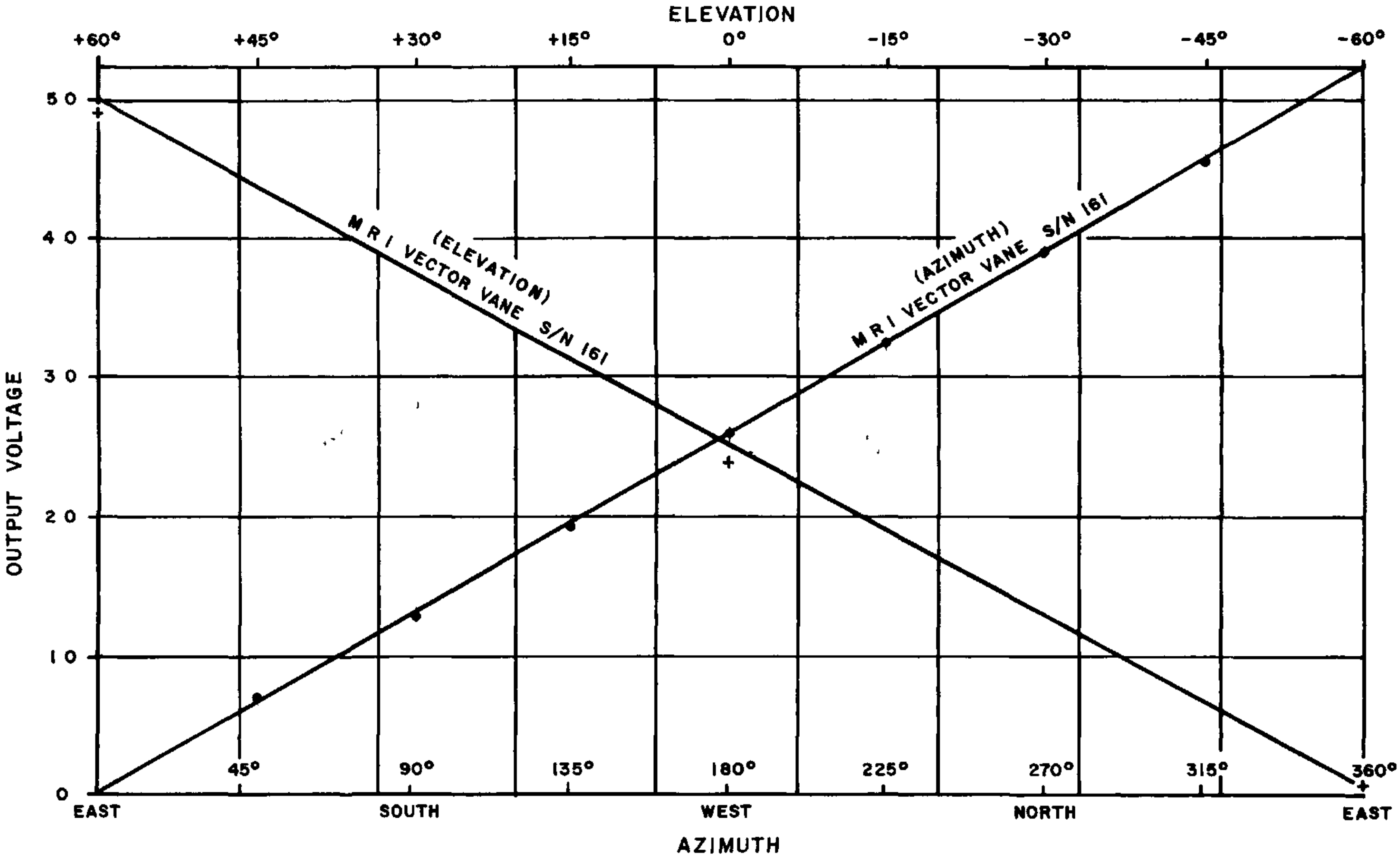


FIG 18. DIRECTION CALIBRATION OF M.R.I. VECTOR VANE

C. Temperature Calibration

The relation of the output voltage of the bridge system to the equivalent temperature was determined by the manufacturer and is expressed in the following equation:

$$\text{Temperature } (^{\circ}F) = -886.28(e^2) + 3644.38e - 40.00, \text{ where } e \text{ is the bridge output voltage.}$$

Using this equation, calculated values of temperature were obtained for specific bridge output voltages as follows:

Bridge Output in Volts	Temperature in Degrees F
0.000	-40.000
0.003	-29.075
0.005	-21.800
0.008	-10.902
0.011	-0.019
0.014	+10.847
0.017	+21.698
0.019	+28.923
0.022	+39.747
0.025	+50.556
0.028	+61.348
0.030	+68.533
0.033	+79.300
0.036	+90.049
0.039	+100.783
0.042	+111.501
0.044	+118.636
0.047	+129.328
0.050	+140.003

Since there is an amplifier between the bridge output and the data measuring system, the above values of "e" are increased 100 times before conversion to digital outputs. The graph of these data is shown in Figure 19. From this the values of the best straight line equation were determined.

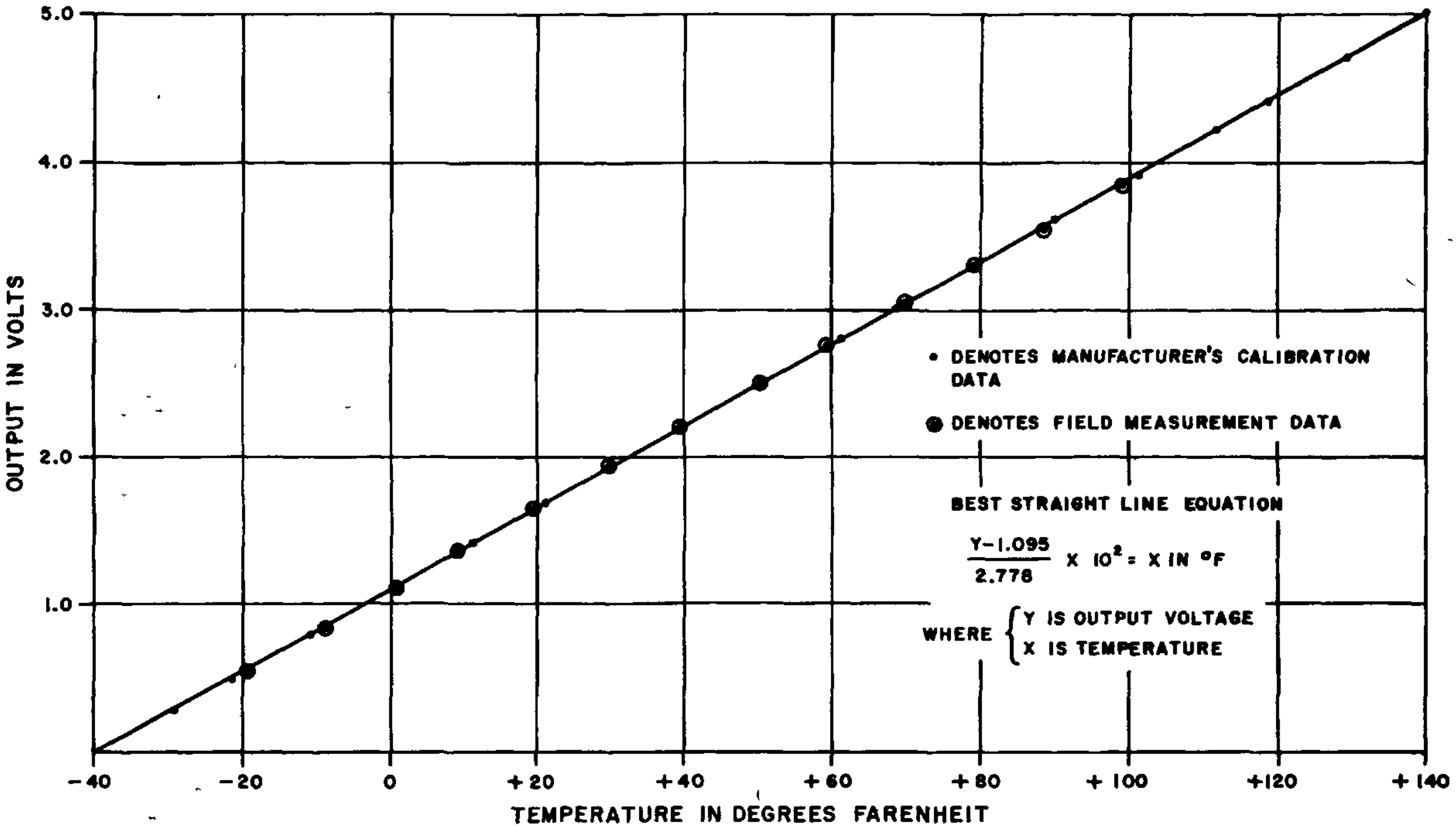


FIG. 19 CALIBRATION OF TEMPERATURE MEASURING SYSTEM

$y = mx + b$ where m is the slope in volts per degree F.

b is the intercept on the voltage axis.

y is the output voltage.

x is the temperature in degrees F.

$$y = 2.778 \times 10^{-2} \text{ volts/degree } (x) + 1.095$$

or

$$\frac{y - 1.095}{2.778} \times 10^{2} = x \text{ (in degrees F)}$$

Using either the graph or the above equation, the values of temperature may be easily determined.

To make the field calibrations of the temperature measuring system a type D-100 temperature chamber was obtained and placed at Site 3. With this chamber it was possible to produce a controlled temperature over the range of -20 to +100 degrees Fahrenheit. A type T thermocouple and a Honeywell resistance bulb, Model 921A3, were both placed in an alcohol bath and the container was positioned in the controlled chamber. The thermocouple reference junction was maintained in an ice bath throughout the calibration run. The resistance bulb was connected to the Model 140 bridge system described above and the output voltages were measured on an accurate digital voltmeter in the data van. The output of the thermocouple was measured by the standard potentiometric method at the field site. The chamber temperature was changed in approximately 10 degree steps over the noted range. Table VII shows the results of this calibration. The resistance bulb data were also plotted on the same graph as the manufacturer's calibration data. See Figure 19. There is excellent agreement between the two calibrations. The standard deviation of the temperature differences obtained by the two measuring methods was $\pm 0.39^{\circ}$ Fahrenheit.

D. Humidity Calibration

Since no chamber was available to provide and control the humidity conditions required for calibration purposes, the manufacturer's calibration data, shown in Figure 20, were used in the field tests. Dewpoint temperatures measured by other methods were compared with those obtained using the Bendix DHGF-1P hygrometer. To obtain meaningful measurements with the instrument required considerable care in the installation, maintenance, and operation. Although this hygrometer was designed for field operation, it was necessary to handle the instrument as a laboratory-type device.

Table VII

Field Calibration Data, Resistance Bulb vs Thermocouple

BRIDGE SYSTEM OUTPUT (VOLTS)	EQUIVALENT TEMPERATURE (°F)	TYPE T THERMOCOUPLE OUTPUT (mv)	EQUIVALENT TEMPERATURE (°F)	TEMPERATURE DIFFERENCE BETWEEN RESISTANCE BULB AND THERMOCOUPLE (°F)
3.86	99.53	+1.519	100.69	-0.56
3.56	88.73	+1.274	89.48	-0.75
3.30	79.37	+1.057	80.00	-0.63
3.03	69.65	+0.830	69.91	-0.26
2.76	59.94	+0.609	60.00	-0.06
2.49	50.22	+0.400	50.50	-0.28
2.20	39.78	+0.169	39.91	-0.13
1.92	29.70	-0.151	29.58	+0.12
1.65	19.98	-0.252	19.90	+0.08
1.37	9.90	-0.471	9.61	+0.29
1.22	4.50	-0.583	4.22	+0.28
1.10	0.34	-0.667	0.38	-0.04
0.833	-9.43	-0.870	-9.91	-0.48
0.556	-19.40	-1.070	-19.89	-0.49

1. The Beckman and Whitley Model 140 Bridge System was used with Honeywell Resistance Bulb Model 921A3 as the temperature sensor.
2. Resistance Bulb and Thermocouple Measuring Junction were in alcohol bath inside Temperature Chamber. The Thermocouple Reference Junction was maintained in an ice bath.
3. The voltages were measured with Digital Voltmeters
4. The temperatures were calculated from available sensor data.

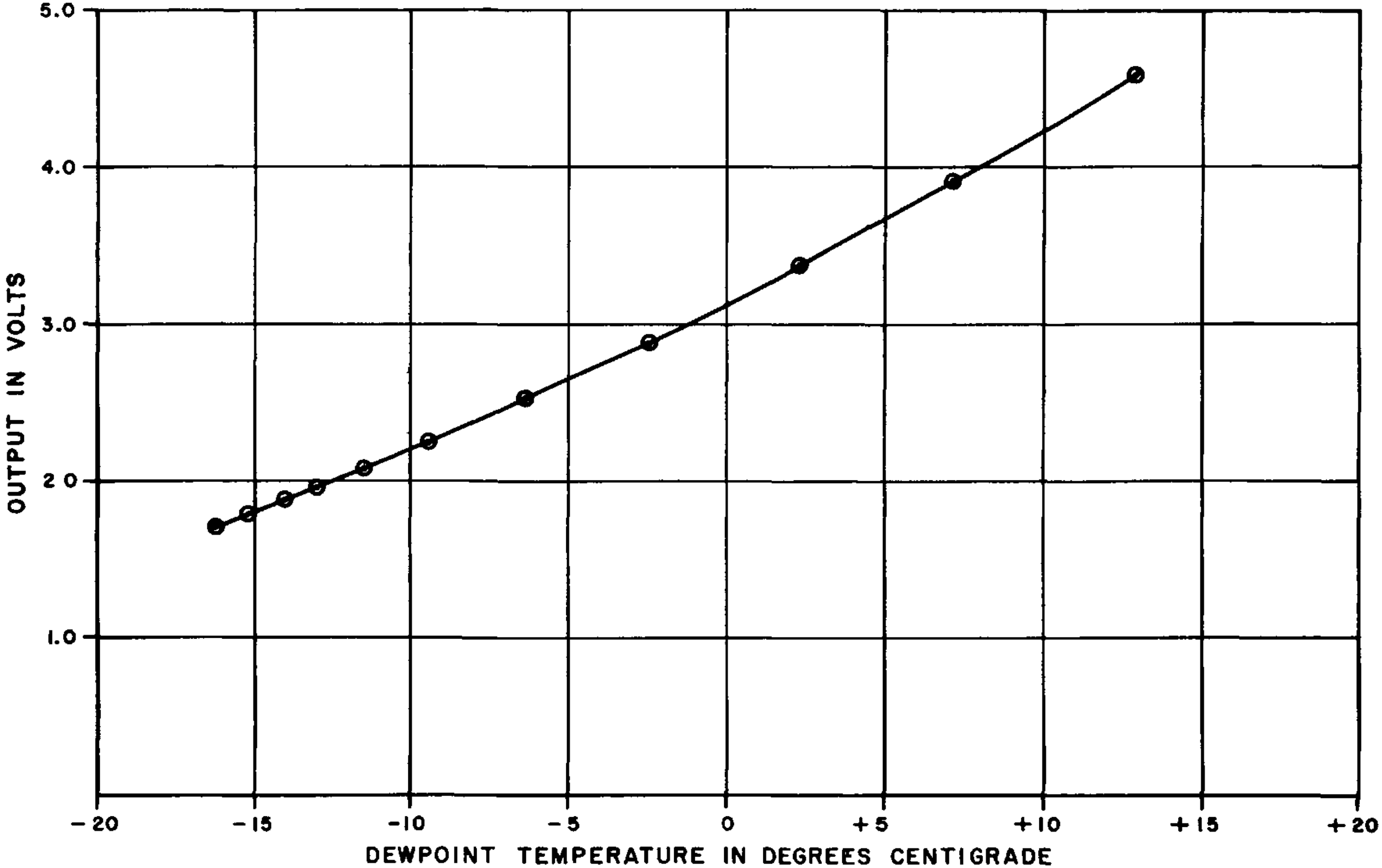


FIG. 20 DEWPOINT HYGROMETER CALIBRATION
(MANUFACTURER'S
DATA)

Field tests were conducted using an ML-24 Psychrometer mounted in a standard instrument shelter to obtain wet bulb and dry bulb temperatures from which the dewpoint temperature could be calculated. Two sensing units of the DHGF-1P hygrometer were placed in the same shelter environment and the output voltages were measured on a digital voltmeter. Using the calibration furnished with each instrument, the dewpoint temperatures were obtained. Table VIII is a summary of this test. The range of dewpoint temperatures measured was 63° to 76° Fahrenheit. The standard deviation of dewpoint temperature between the psychrometer data and that of the first hygrometer was $\pm 3.07^{\circ}$ F and between the psychrometer data and that of the second hygrometer was $\pm 3.08^{\circ}$ F. On the second day's run the standard deviation was $\pm 3.8^{\circ}$ F for the first unit. Comparison between the two hygrometer results was very good. The results indicate the need for a better method of producing a wider range, controlled, humidity environment so that the hygrometer units can be more precisely calibrated.

A very simple method of obtaining the wet bulb temperature (required for the dewpoint temperature calculation) with the use of a Honeywell 921A3 resistance bulb was tried. A wick was placed over the bulb end and kept saturated with water in the same manner that a wet bulb thermometer is used in the ML-24 psychrometer. The equivalent wet bulb temperature was then measured using the standard bridge system already described. The dry bulb temperature was obtained in the normal fashion on a second channel of the bridge system. Table IX is a summary of this simple test. The temperature range was from approximately 33° to 43° F and the average value of temperature readings of the precision wet bulb thermometer was $34.28 \pm 1^{\circ}$ F and was $34.17 \pm 2.7^{\circ}$ F for the wet bulb resistance sensor. The dry bulb readings were respectively $40.47 \pm 2.3^{\circ}$ F and $39.18 \pm 2.1^{\circ}$F. This indicates that the calculated dewpoint temperature could be obtained as accurately from the resistance bulb measurements as from the thermometer measurements, at least over this narrow range. More precise measurements will still require field operational hygrometers which have been most carefully calibrated in a controlled environment.

Table VIII

Field Dewpoint Temperature Measurements

	ML-24 PSYCHROMETER TEMPERATURE IN °F.				BENDIX HYGROMETER MODEL DHGF-1P			
					SERIAL 101		SERIAL 102	
TIME	DRY BULB	WET BULB	DEW POINT	% RELATIVE HUMIDITY	(2)MEASURED OUTPUT V.	(3)DEW POINT TEMP °F	(2)MEASURED OUTPUT V.	(3)DEW POINT TEMP °F
25 Aug 65								
0900	70.6	65.0	62.0	74	5.10	65.3	5.40	64.9
0915	71.5	65.1	61.6	71	5.11	65.5	5.42	65.1
0930	72.0	65.0	61.2	68	5.09	65.1	5.41	64.9
0945	72.0	65.5	62.0	70	5.10	65.3	5.42	65.1
1000	72.0	66.0	62.8	72	5.19	66.6	5.52	66.7
1015	71.5	66.9	64.6	78	5.23	66.9	5.56	67.1
1030	72.0	67.2	64.8	78	5.22	66.9	5.53	66.7
1045	72.8	66.6	63.4	72	5.20	66.7	5.54	66.7
1100	73.5	66.9	63.5	70	5.12	65.5	5.44	65.5
1115	73.1	64.9	60.4	64	4.97	63.5	5.27	63.5
1130	73.2	65.1	60.6	65	5.00	64.0	5.31	64.0
1145	73.0	65.8	62.0	68	5.03	64.0	5.35	64.6
1200	73.2	65.7	61.7	67	5.02	64.0	5.34	64.6
1500	79.0	66.8	60.3	53	4.94	63.1	5.29	63.9
1515	79.1	67.0	60.5	53	5.03	64.0	-	-
					STD DEV	-3.07		-3.08
26 Aug 65								
0700	69.0	68.5	68.2	97	5.61	72.0	-	-
0715	69.0	68.5	68.2	97	5.60	72.0	-	-
0730	69.4	68.9	68.6	97	5.60	72.0	-	-
0745	70.0	69.0	68.1	94	5.62	72.0	-	-
0800	70.2	69.1	68.6	94	5.65	72.5	-	-
1200	78.3	74.0	72.3	81	5.96	76.3		
					STD DEV	-3.8		

NOTES: (1) Barometric Pressure dropped from 30.0 inches to 29.9 inches during run.
(2) Output voltages measured on Digital Voltmeter.
(3) Dew Point Temperature obtained from manufacturer's calibration curve.

Table IX

Wet/Dry Bulb Temperature Comparison Tests

DATE/TIME	TEMPERATURE PRECISION THERMOMETER °F		CALCULATED DEWPOINT TEMPERATURE °F	TEMPERATURE HONEYWELL BULB °F		BAROMETRIC PRESSURE IN (MILLIBARS)
7 DEC. 65	WET	DRY		WET	DRY	
13:30	33.5	40.8	20.1	33.33	40.39	1023.5
13:45	33.6	41.2	19.5	33.69	40.75	1023.6
14:00	33.3	41.3	18.0	33.59	40.57	1023.6
14:15	34.2	42.5	19.7	34.41	41.18	1023.6
14:30	33.7	41.6	19.0	33.62	40.89	1023.6
8 DEC. 65						
09:15	32.4	35.8	27.3	32.33	34.77	1021.0
09:30	32.5	35.7	27.7	32.40	34.70	1020.8
09:45	33.0	36.5	27.7	32.87	35.82	1020.5
10:00	33.0	38.1	24.9	34.16	36.90	1020.3
10:15	34.1	38.5	27.5	33.77	37.04	1020.2
10:30	34.3	38.5	28.1	34.05	37.33	1019.7
10:45	34.4	38.6	28.2	34.27	37.76	1019.8
11:00	35.4	40.9	27.3	35.06	39.30	1019.7
11:15	35.7	41.9	26.6	35.03	39.52	1019.7
13:30	34.1	40.8	23.5	34.02	39.78	1017.6
13:45	35.1	41.9	24.6	35.13	41.00	1017.6
14:00	35.6	43.4	23.5	35.46	41.58	1017.6
14:15	34.5	41.5	25.4	34.31	40.06	1017.7
14:30	34.9	41.2	25.3	34.63	39.96	1017.7
14:45	35.0	42.0	24.3	34.70	39.99	1017.9
15:00	35.2	42.1	24.7	34.92	40.10	1018.0
15:15	35.7	43.0	24.5	35.13	40.78	1018.2
15:30	35.2	43.0	22.5	35.03	41.07	1018.2
Average:	34.28	40.47	Average:	34.17	39.18	
Std. Dev:	± 1.0	± 2.3	Std. Dev:	± 2.7	± 2.1	

VI. RANGE PROGRAMS

The first field program carried out after the installation of the digital acquisition system, the signal lines, and the instrumentation shelters was run with 14 wind speed sensors and 14 wind direction sensors of type AN/GMQ-12. Since the sensor towers had not yet been installed, one speed sensor and one direction sensor were mounted at the ends of the standard AN/GMQ-12 T-bar supported by a 5-foot high tripod. These tripods were placed in a line 100 feet apart along the east side of the range. After the sensor calibrations were completed a series of data gathering runs was made with the output recorded digitally on magnetic tapes. These were turned over to personnel of the Exterior Ballistics Laboratory (EBL) who supervised the computation and data analysis; the results will be contained in a forthcoming report.

Table X is a summary of the field runs made during this program. The data were acquired over a rather long time period in order to obtain a range of wind speed from 3 to 30 miles per hour and wind direction from several compass points. The first few runs were made with a complete scan of all sensors each second for a total run time of 30 seconds at half-hour intervals. During later runs the scan rate was increased to 10 per second for a 30 second run at hourly intervals. A total of 62 data runs were made producing 8610 total scans of the sensors.

Another program was carried out to measure temperatures at various tower levels at the first four tower sites. Both types of temperature sensors previously described were used and measurements were made at ten minute intervals on three separate days. Table XI is a summary of these data. Variations in the temperature from one tower level to another and from tower to tower are clearly shown. Wind speed data acquired on a field program are included in Table XII to show results obtained with two different types of sensors located on the same T-bar mount, tripod supported. The tabulated values were extracted from printouts of digital data recorded on several runs on the days noted. These typical data show the variations in wind speed that were recorded using two types of previously calibrated sensors located only three feet apart.

Table X

Data Summary, Field Test Using AN/GMQ-12 Sensors

Date	Wind Speed Channels	Wind Direction Channels	Scan Rate	Data Run Time	Number of Runs	Rate of Runs	Prevailing Wind Direction	Prevailing Wind Velocity MPH
(1964)								
21 Aug	13	14	1/sec	30 secs.	4	ea 1/2 hr	-	-
26 Aug	13	14	1/sec	30 secs.	5	ea 1/2 hr	-	-
3 Sep	13	13	1/sec	30 secs.	6	ea 1/2 hr	WSW	3-7
4 Sep	14	14	1/sec	30 secs.	8	ea 1/2 hr	NNE	3-5
6 Oct	14	14	1/sec	30 secs.	7	ea 1/2 hr	NE	20-30
9 Oct	14	14	10/sec	30 secs.	7	ea 1/2 hr	-	-
11 Dec	14	14	10/sec	30 secs.	5	ea 1/2 hr	-	-
14 Dec	14	14	10/sec	30 secs.	6	ea 1/2 hr	NW	7-13
(1965)								
6 Jan	14	14	10/sec	30 secs.	5	ea hr	NNW	15
7 Jan	14	14	10/sec	30 secs.	4	ea hr	NE-2	4
							S-2	10
8 Jan	14	14	10/sec	30 secs.	5	ea hr	S-SSW	7

TOTAL DATA RUNS: 62
TOTAL SCANS: 8610

Table XI

Field Temperature Measurements Using Bridge System

DATE	SENSOR B&W 60.1		SENSOR B&W 60.1		SENSOR B&W 60.1		SENSOR HONEYWELL 921A3		SENSOR B&W 60.1	
	SITE 1 TOP LEVEL		SITE 2 TOP LEVEL		SITE 3 TOP LEVEL		SITE 3 MDL LEVEL		SITE 4 TOP LEVEL	
	OUTPUT IN VOLTS	TEMP IN ^oF	OUTPUT IN VOLTS	TEMP IN ^oF	OUTPUT IN VOLTS	TEMP IN ^oF	OUTPUT IN VOLTS	TEMP IN ^oF	OUTPUT IN VOLTS	TEMP IN ^oF
J	3.2601	77.94	3.3200	80.09	3.3001	79.38	3.2803	78.66	3.2879	78.93
U	3.2800	78.65	3.3179	80.02	3.2999	79.37	3.2899	79.01	3.2877	78.93
L	3.2899	79.01	3.3200	80.09	3.2879	78.93	3.2807	78.68	3.2899	70.01
Y	3.2799	78.65	3.3099	79.73	3.2879	78.93	3.2629	78.01	3.2790	78.62
	3.2720	78.37	3.3007	79.40	3.2803	78.66	3.2699	77.93	3.2701	78.30
15	3.2600	77.93	3.2800	78.65	3.2801	78.66	3.2519	77.64	3.2640	78.06
	3.2600	77.93	3.2803	78.66	3.2801	78.66	3.2507	77.60	3.2619	78.00
65	3.2480	77.50	3.2999	79.37	3.2778	78.57	3.2507	77.60	3.2601	77.94
	3.2479	77.50	3.2800	78.65	3.2779	78.58	3.2559	77.79	3.2635	78.06
	B&W 60.1		B&W 60.1		HONEYWELL 921A3		HONEYWELL 921A3		B&W 60.1	
	SITE 1 TOP LEVEL		SITE 3 TOP LEVEL		SITE 3 MDL LEVEL		SITE 3 BTM LEVEL		SITE 4 TOP LEVEL	
J	2.8690	63.86	2.8800	64.25	2.8729	64.00	2.8819	64.32	2.8819	64.32
U	2.8803	64.27	2.9170	65.59	2.8979	64.90	2.9079	65.26	2.8879	64.54
L	2.8999	64.97	2.9298	66.05	2.9201	65.70	2.9279	65.98	2.9180	65.62
Y	2.9379	66.34	2.9278	65.98	2.9200	65.69	2.9280	65.98	2.9439	66.56
20	2.9201	65.70	2.9379	66.34	2.9179	65.62	2.9400	66.41	2.9479	66.70
	2.9400	66.41	2.9399	66.41	2.9239	65.84	2.9427	66.51	2.9399	66.41
65	2.9400	66.41	2.9379	66.34	2.9400	66.41	2.9599	67.13	2.9400	66.41
J	2.9407	66.44	2.9629	67.24	2.9449	66.59	2.9839	67.99	2.9620	67.21
U	2.9800	67.85	2.9798	67.85	2.9711	67.53	2.9794	67.83	2.9901	68.22
L	2.9801	67.86	2.9699	67.49	2.9600	67.35	2.9740	67.64	2.9939	68.35
Y	2.9799	67.85	2.9878	68.14	2.9681	67.43	2.9737	67.63	2.9959	68.43
21	3.0201	69.30	2.9898	68.21	2.9817	67.92	3.0000	68.57	3.0180	69.22
	3.0201	69.30	2.9980	68.50	2.9843	68.01	3.0064	68.80	3.0109	68.97
65	3.0401	70.02	3.0215	69.35	3.0059	68.79	3.0200	69.29	3.0320	69.73

1. Measurements were made at 10 minute intervals.
2. Sensors were tower mounted in aspirated thermal shields.
3. Blower fans were on.

Table XII

Wind Speed Comparison Data

	16 NOV. 65 WIND SPEED IN M.P.H.			17 NOV. 65 WIND SPEED IN M.P.H.			19 NOV. 65 WIND SPEED IN M.P.H.	
TIME	SENSOR A SER. 144	SENSOR B SER. 21	TIME	SENSOR A SER. 144	SENSOR B SER. 21	TIME	SENSOR A SER. 144	SENSOR B SER. 21
08:40	10.4	9.8	08:40	24.7	27.9	08:30	6.6	6.3
08:50	19.1	19.7	08:50	-	-	08:40	8.1	10.0
09:00	18.0	19.1	09:00	8.5	9.4	08:50	4.1	5.3
09:10	18.1	18.7	09:10	10.0	12.3	09:00	-	-
09:20	18.3	17.5	09:20	-	-	09:10	8.1	9.3
09:30	18.6	19.5	09:30	-	-	09:20	7.5	8.0
09:40	16.9	15.2	09:40	16.3	18.4	09:30	4.6	5.0
09:50	17.1	14.4	09:50	11.5	9.9	09:40	7.0	8.4
10:00	-	-	10:00	18.5	20.1	09:50	8.3	10.0
10:10	15.7	14.4	10:10	9.6	11.2	10:00	7.6	8.3
10:20	10.4	11.9	10:20	15.6	15.0	10:10	5.2	5.7
10:30	13.2	13.6	10:30	12.7	13.5	10:20	5.7	7.2
						10:30	7.7	7.5
*12:00	5.6	6.3	13:30	18.1	17.7	10:40	-	-
12:10	5.4	5.9	13:40	14.3	16.3	10:50	6.5	8.3
12:20	8.1	8.9	13:50	23.7	25.5	11:00	10.1	12.1
12:30	8.7	9.6	14:00	14.8	13.7			
12:40	11.4	12.2	14:10	16.6	19.1	13:00	6.3	7.7
12:50	6.7	8.4	14:20	-	-	13:10	5.8	7.0
13:00	13.1	12.9	14:30	15.7	19.1	13:20	4.9	5.8
13:10	7.3	9.0	14:40	21.5	25.2	13:30	8.9	9.7
13:20	7.7	8.9	14:50	13.9	14.6	13:40	9.0	10.6
13:30	6.5	7.8	15:00	23.0	22.0	13:50	5.5	7.2
13:40	6.2	8.6	15:10	12.8	14.6	14:00	6.4	8.3
13:50	8.0	9.1	15:20	-	-	14:10	5.4	7.7
14:00	7.5	8.8	15:30	13.5	14.5	14:20	5.6	8.5
Pressure:	1007.6 mb. to 1002.8 mb.		Pressure:	1000.3 mb. to 998.7 mb.		Pressure:	1016.2 mb. to 1015.6 mb.	

*Rain during 2 hour run. Std. Dev. is ± 1.5

Sensor A· AM/GMQ/12 Sen-or B: Beckman and Whitley, Series 50

VII. SUMMARY

The measurements provided by both calibration and range programs indicate that the range facility is capable of furnishing the required support for fundamental research in the near-earth environment.

The multi-channel, high-speed, analog-to-digital conversion system with the output digital data presented on magnetic tape in a compatible computer format allows the use of many more input sensors than was previously practical. The rate of acquiring data has been greatly enhanced to allow more detailed analysis of desired parameters of a system under study. The many advantages of computers can now be brought into use on many more types of field programs. This facet has not yet been fully exploited on data obtained on the range facility. The system is not limited to use with meteorological sensors but is capable of acquiring data from any input device producing an analog voltage output within the system specifications.

At the present time the types of meteorological sensors available for use on the range are much too slow in response to approach the requirements of certain projects and to meet the sampling speed of the digital system. Effort should be spent to acquire improved sensors giving faster response and increased accuracy. Coupled with this are the requirements for improved methods of calibration, both for increased accuracy and ease of the field calibration operations. Coordination with and assistance from both commercial manufacturers and other government agencies will be necessary to obtain the desired instruments.

It is planned that future operations on the range facility will include not only the gathering of meteorological data but data from both optical and electronic devices. Installation of the additional required facilities for these types of measurements has begun.

The field operations of the Army Meteorological Team assigned to this project have been very satisfactory and the team has served an important part in the installation and use of the range facilities.

CHANNING L. ADAMS

APPENDIX A

RANGE OPERATIONS

Installation of the range facilities was made with the purpose of obtaining as much flexibility and versatility as possible where a large number of several different types of sensors and associated circuits would be used in various configurations. Although all possible layouts could not be foreseen, the overall system lends itself to relatively fast changes of sensors and cabling at the various towers and at different tower levels.

The signal cables to the data acquisition van are permanently installed but quick access is available to them through proper terminations at each instrument shelter for fast changeover from program to program. This also allows analog outputs from other systems to be fed into the digital data section.

A meteorological team was assigned to BRL by the U.S. Army Electronics R&D Activity at Fort Hauchuca, Arizona for use in the field operations on the range. This team has worked very well in carrying out such functions as field installations of cabling and sensors with associated circuits, the field calibrations of sensors, the maintenance and repair of various types of meteorological equipment, and the calculation of results from observed data. In addition, since May 1965 daily records of meteorological data have been made at the van site and tabulated by the team. The type of measurements made and the equipment used are as follows:

1. Atmospheric Pressure: Surface to 3000 ft., precision Microbarograph, Belfort Instrument Company, Model 5-800.
2. Temperature: -50° to $+140^{\circ}$ F, Hygrothermograph, Instruments Corporation, Model 594.
3. Relative Humidity: 5 percent to 100 percent, Hygrothermograph, Instruments Corporation, Model 594.
4. Precipitation: 0 to 12 inches, Universal weighing rain gage, Friez Instruments Division, Model 775 B.

5. Wind Speed: 1 to 60 mph, Wind measuring set AN/GMQ-12.

6. Wind Direction: 354° azimuth, Wind measuring set AN/GMQ-12.

Appendix B includes the monthly summary of these data from 1 May 65 through 31 January 66.

The following summary indicates the system type and the number of units presently available for field use:

	Measurement	Number	Data Channels Required
1.	Wind Speed and Direction AN/GMQ-12	30	60
	M.R.I. Vector Vane Model 1053	12	36
	B.&W. Series 50	2	4
2.	Temperature		
	Resistance Bulb, Honeywell 921A3	18	36
3.	Humidity		
	Bendix Hygrometer, Model DHGF-1P	5	5
	Wet/Dry Resistance Bulb	9	18

Characteristics of the various systems are contained in Tables AI, AII, and AIII.

Table AI

Characteristics of AN/GMQ12 Wind Measuring Set and Climet Speed Sensor, Model 011-1

	AN/GMQ-12	CLIMET, Model 011-1
A. Wind Speed Sensor:		
(1) Range	1-60 mph	0-90 mph
(2) Threshold	1 mph	1 mph
(3) Accuracy	± 5 percent	± 5 percent
(4) Response	-	5 feet (63 percent recovery)
B. Wind Direction Sensor:		
(1) Range	354°	-
(2) Threshold	1 mph	-
(3) Accuracy	± 3 percent	-
C. Power Requirement:	(Overall 110 volt AC 60 cycle at 20 Amp)	(Speed Sensor Only) 10.6-12.6 volts DC at 30 milliamps

Table AII

Characteristics of Vector Vane Windspeed and Direction Sensor, Meteorology Research Incorporated 1053

A. RESPONSE CHARACTERISTICS:

1.	Starting Threshold:	Speed	0.5 mph
		Direction	0.5 mph
2.	Response Distance:	Speed	2-3 feet (63 percent recovery)
3.	Delay Distance:	Direction	2-3 feet (50 percent recovery)
4.	Damping Ratio:	Direction	0.4-0.7
5.	Overshoot:	Direction	Less than 10 percent
6.	Linearity:	Speed	$\pm$ 1 percent of pitch
		Direction	$\pm$ 1 percent
7.	Matching:	-	The sensor elements are considered matched if the response distance and delay distance are within one foot of each other.

B. OUTPUT CHARACTERISTICS:

1. Direction, azimuth	
a. Full scale	2000 ohms $\pm$ 5 percent
b. Linearity	$\pm$ 0.8 percent of full scale (with 4° open space)
c. Resolution	1°
d. Maximum Power	1.5 watts
2. Direction, elevation	
a. Total Resistance	6000 ohms $\pm$ 5 percent
b. Full Scale (1/3 segment)	2000 ohms
c. Linearity	$\pm$ 0.8 percent
d. Resolution	1°
e. Maximum Power	0.5 watts
3. Speed	
a. Pitch	2.90 feet per revolution
b. Signal	20 pulses per revolution
c. Resolution	0.145 feet
4. Range	
a. Direction, azimuth	0 - 356°
b. Direction, elevation	$\pm$ 60°
C. Speed	0.5 - 100 mph

Table AIII

Characteristics of Windspeed and Direction Sensor, Beckman and Whitley Series 50

A. Wind Speed Sensor: (with staggered-six cup anemometer)

1. Threshold: 0.5 miles per hour
2. Distance Constant: 3.3 feet of Air
3. Accuracy: $\pm$ 1 percent of absolute value or $\pm$ 0.15 miles per hour, whichever is greater.
4. Range: From threshold to 90 miles per hour
5. Nominal Output: 2.5 volts p-p into 600 ohm load over the frequency range of 1018 cps (0.5 mph) to 1059 cps (90 mph)
6. Power Requirement: 12 volts DC, nominal at a maximum current drain of 20 milliamperes
7. Operating Temperature: $-40\ ^{\circ}F$ to $+140^{\circ}F$

B. Wind Direction Sensor: (with "Quick One" wind vane)

1. Threshold: 0.7 miles per hour at 10°
2. Distance Constant: 5.7 feet of air
3. Damping Ratio: 0.6
4. Accuracy: $\pm 2^{\circ}$
5. Output: Phase modulation at 1 KC over full 360°
6. Power Requirement: 12 volts DC at maximum current drain of 10 milliamperes
7. Operating Temperature: $-40^{\circ}F$ to $+140^{\circ}F$

C. Modular Translator:

(a) Power Supply

1. Input: 115 volts AC $\pm$ 10 percent
2. Output Voltage: 12 volts DC, 0.1 percent regulation
3. Maximum Current Output: 600 milliamperes

Table AIII (Cont'd)

(b) Translators

		Wind Speed	Wind Direction
1.	Signal Input	0.5 to 3.0 volts P-P	0.35 to 0.5 volts rms
2.	Input Impedance	600 ohms	600 ohms
3.	Accuracy	DC Output voltage linearly propor-ional to speed ± 0.3 percent	DC Output voltage linearly propor-tional to phase angle between two input signals ± 0.15 percent
4.	Power Input	12 volts DC at 40 milliamperes regulated to 0.1 percent	12 volts DC at 60 milliamperes regu-lated to 0.1 per-cent

APPENDIX B

METEOROLOGICAL DATA SUMMARIES
MAY 1965 - JANUARY 1966

METEOROLOGICAL DATA TABULATION SHEET

DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS

PERIOD 6 HOURS

LOCATION ABERDEEN PROVING GROUND MD

SITE E M P RANGE ON SPESUTIE ISLAND

TIME ZONE EASTERN

MONTH MAY

YEAR 1965

DAY	* TEMPERATURE °F 8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN HG 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP IN INCHES	DAY
1	58	64	60	67	68	52	62	53	30 06	30 07	30 07	30 06	-	-	-	-	-	-	-	-	03	1
2	54	56	64	65	88	80	70	77	30 02	30 02	30 01	30.00	-	-	-	-	-	-	-	-	02	2
3	58	-	-	-	91	70	52	45	30 08	30 08	30 08	30 08	-	-	-	-	-	-	-	-		3
4	68	76	82	85	91	44	33	25	30 02	30 02	30.02	30.02	-	-	-	-	-	-	-	-		4
5	60	62	64	66	65	77	69	70	30.10	30.11	30.12	30.13	-	-	-	-	-	-	-	-	.04	5
6	53	55	59	62	89	83	77	71	30.12	30.13	30.16	30.16	-	-	-	-	-	-	-	-		6
7	51	51	52	54	74	68	94	82	30.29	30.28	30.26	30.25	-	-	-	-	-	-	-	-	.29	7
8	49	52	53	54	96	96	98	96	30.22	30.23	30.23	30.22	-	-	-	-	-	-	-	-		8
9	55	57	60	64	97	90	80	74	30.17	30.17	30.16	30.14	-	-	-	-	-	-	-	-		9
10	67	70	76	65	92	86	70	42	29 98	29 98	29 95	29 91	-	7	13	9	-	SSW	S	NW		10
11	73	76	80	83	76	64	56	46	29 89	29 90	29 88	29 86	12	12	10	15	WSW	NW	W	WSW	80	11
12	60	65	68	71	64	56	52	52	29 91	29 90	29 87	29 82	7	4	7	7	NW	NNW	S	S		12
13	64	68	73	74	62	57	55	51	29 76	29 76	29 75	29 74	[illegible]	[illegible]	10	14	NW	NW	NNW	NNW		13
14	53	58	61	64	53	51	47	43	30 09	30 11	30 13	30 10	10	8	5	7	NNE	ENE	ESE	E		14
15	56	59	55	69	66	66	51	49	30 19	30 19	30 17	30 15	7	10	12	12	SSW	SW	SW	WSW		15
16	61	60	66	75	87	9[illegible]	79	59	30 07	30 05	30 03	29 99	1	1	3	2	SSW	SSW	SSW	SSW		16
17	65	71	78	81	100	82	59	50	29 85	29 85	29 82	29 78	3	5	7	10	S	ENE	S	S		17
18	59	63	68	71	65	59	53	47	29 91	29 91	29 91	29 91	8	9	12	16	NW	NNW	NW	NW		18
19	63	70	74	78	88	64	59	49	30 02	30 03	30 03	30 00	4	5	10	14	NNE	SE	SSW	SSW		19
20	62	67	71	72	79	61	56	54	30 17	30 18	30 18	30 16	8	8	4	4	NNE	NE	NE	E		20
21	62	65	68	69	68	67	63	63	30 30	30 34	30 33	30 32	12	14	9	10	NE	ENE	E	ESE		21
22	57	62	69	73	96	85	72	68	30 30	30 29	30 27	30 22	5	6	4	5	SE	SSW	SSW	SSW		22
23	68	73	79	86	88	76	62	60	30.14	30.16	30 15	30 12	3	0	0	2	W	-	-	E		23
24	58	58	56	58	83	80	86	83	30.29	30.31	30.34	30.32	3	18	15	8	NE	ENE	ENE	E		24
25	60	65	68	71	84	84	77	72	30 13	30 10	30 06	30 00	8	11	15	15	SSW	SSW	SSW	SSW	06	25
26	69	65	81	81	86	77	63	62	29 87	29 86	29 85	29 82	2	5	6	7	SSW	SSW	NSW	SSW		26
27	72	77	85	86	99	67	67	61	29 82	29 79	29 77	29 74	2	4	5	12	SW	ESE	S	S	13	27
28	73	75	78	80	54	67	50	46	29.87	29 87	29 87	29 8[illegible]	5	8	13	13	NNW	WNW	W	W		28
29	54	58	61	64	95	87	71	67	29.94	29.94	29 94	29 90	4	4	9	8	S	SSW	SSW	S	50	29
30	52	56	59	60	59	51	19	48	30.10	30.12	30.10	30.06	7	6	8	7	NNE	N	ENE	SE		30
31	59	61	67	69	74	54	45	44	30 08	30 08	30 08	30 04	2	4	10	13	S	S	S	S		31
MONTHLY VALUES																					1 87	

TABULATED BY APG MET TEAM

VERIFIED BY

REMARKS

* Indicates time of day the charts were read, 0800 1000, 1200, & 1400

SELWU Form 1010
1 Mar 69

USAEPG FORT HUACHUCA ARIZONA

METEOROLOGICAL DATA TABULATION SHEET

DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS

PERIOD 6 HOURS

LOCATION ABERDEEN PROVING GROUND, MD

SITE E M P RANGE ON SPESUTIE ISLAND

TIME ZONE EASTERN

MONTH JUNE

YEAR 1965

DAY	TEMPERATURE °F * 8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN HG 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP IN INCHES		
1	66	71	74	80	84	70	66	49	30 07	30 08	30 06	30 06	6	3	8	10	W	S	S	S			1
2	69	73	76	81	86	68	63	58	29 97	29 96	29 92	29 87	7	4	8	8	SW	SSW	S	S		.55	2
3	57	59	65	68	96	80	65	52	29 92	29 95	29 99	29 98	20	15	10	7	N	NNE	N	NW			3
4	59	63	65	68	60	51	46	47	30 19	30 20	30 20	30.19	9	7	6	4	NNE	NNE	NE	SE			4
5	60	66	68	72	69	61	54	47	30.21	30.22	30.21	30.20	1	6	8	9	WSW	WSW	WSW	WSW			5
6	65	69	74	77	77	69	61	56	30.19	30.20	30.19	30.17	12	10	7	10	S	WSW	S	S			6
7	71	74	80	84	87	75	62	58	30.11	30.11	30.09	30.06	8	12	13	13	SSW	SSW	SSW	SSW			7
8	72	77	82	86	92	82	69	60	30.06	30.10	30.06	30.01	9	13	12	13	S	SSW	SSW	S	1	.63	8
9	72	72	73	76	95	91	90	83	30.02	30.02	30.02	30.00	7	12	16	17	S	SSW	S	S			9
10	73	78	79	86	95	88	81	54	29.98	29.98	29.96	29.93	3	6	12	14	SW	SSW	SSW	WSW			10
11	68	71	73	76	63	54	54	54	30.07	30.07	30.04	30.00	0	0	5	9	-	-	ESE	SE			11
12	72	72	75	78	75	61	55	48	29.80	29.80	29.77	29.72	-	-	-	-	WNW	NNE	NNE	NE			12
13	67	68	70	73	51	53	47	41	29.65	29.68	29.69	29.70	-	-	-	-	W	NW	NNW	NNW			13
14	63	64	68	70	69	60	56	53	29 90	29 94	29 94	29 94	3	4	8	8	S	ENE	SE	S			14
15	61	65	66	65	90	77	68	64	30 12	30 16	30 17	30 18	13	17	18	21	ENE	E	ESE	ESE		.10	15
16	54	56	57	56	98	90	78	86	30 17	30 17	30 17	30 16	20	20	20	22	ENE	NE	NE	NE			16
17	57	61	63	64	66	70	65	62	30 15	30 14	30 14	30 12	8	10	7	4	NNE	NNE	NNE	ESE			17
18	57	60	60	64	92	79	73	66	30 05	30 05	30 05	30 03	7	9	10	13	NNW	NNW	NW	NW		.04	18
19	62	67	66	75	69	63	77	62	29 90	29 89	29 90	29 85	6	13	8	6	NNW	NW	NW	NW		.07	19
20	-	-	-	-	-	-	-	-	29.89	29.92	29.92	29.91	5	5	7	5	SSW	S	NNW	ESE			20
21	-	-	-	84	-	-	-	58	29 93	29 93	29 92	29 90	7	9	12	12	SSW	SSW	SSW	SSW			21
22	70	79	82	85	94	74	62	60	30.01	30.03	30.03	30.01	0	7	9	13	-	SSW	SSW	SSW			22
23	75	79	84	88	94	76	67	54	30.02	30.02	30.02	29.98	6	10	13	11	SSW	SSW	SSW	SSW			23
24	74	78	77	74	88	67	67	83	29.89	29.90	29.90	29.90	6	10	8	9	SSW	SW	W	SSW		.04	24
25	60	67	71	74	63	51	47	43	30.08	30.13	30.14	30.12	12	8	8	8	NNE	NNE	N	NNW			25
26	64	70	74	76	54	48	43	37	30.33	30.35	30.37	30.37	10	6	8	8	NNE	NE	NE	N			26
27	64	68	73	76	84	62	48	42	30.48	30.51	30.51	30.49	3	1	0	6	SSW	NNW	-	E			27
28	70	73	77	84	86	84	74	58	30.34	30.30	30.28	30.23	7	13	10	12	SE	SSW	SSW	SSW			28
29	78	82	88	89	70	78	55	53	30.02	30.01	29.98	29.94	9	6	8	8	SW	SSW	SSW	SN			29
30	75	74	72	76	87	68	78	78	29.90	29.92	29.94	29.92	0	9	10	9	-	NNW	NNW	NNE			30
MONTHLY VALUES																					2	43	

TABULATED BY APG MET TEAM

VERIFIED BY

REMARKS * Indicates time of day the charts were read, 0800, 1000, 1200 & 1400

SELWU Form 1010
1 Mar 63

USAEPG FORT HUACHUCA ARIZONA

METEOROLOGICAL DATA TABULATION SHEET

DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS

PERIOD 6 HOURS

LOCATION ABERDEEN PROVING GROUND MD

SITE E M P RANGE ON SPESUTIE ISLAND

TIME ZONE EASTERN

MONTH JULY

YEAR 1965

DAY	* TEMPERATURE °F 8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN HG 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP IN INCHES		DAY
1	68	74	78	80	60	41	35	30	30 12	30 14	30 13	30 12	17	13	8	5	NNW	N	N	NE			1
2	71	72	78	80	64	53	46	44	30 16	30 16	30 14	30 10	7	10	11	7	S	SSW	-	-			2
3	70	72	74	77	70	78	68	60	29 87	29 85	29 84	29 82	17	17	14	14	-	-	-	-			3
4	70	77	82	86	83	60	45	42	29 97	29 98	29 97	29 96	7	4	5	7	-	-	-	-			4
5	70	74	79	83	94	96	78	68	29 93	29 92	29 91	29 86	6	5	8	10	-	-	-	-			5
6	70	75	78	79	94	74	62	56	30 01	30 05	30 10	30 08	8	12	12	8	N	N	NNW	NNW			6
7	67	72	76	82	92	70	64	49	30 13	30 12	30 10	30 04	6	10	10	13	ESE	S	S	S			7
8	74	79	81	83	81	72	62	61	29 89	29 89	29 90	29 89	5	5	5	6	WSW	NNW	S	S			8
9	76	84	88	90	97	69	53	53	29 94	29 94	29 93	29 90	4	8	11	13	S	S	S	S			9
10	78	80	76	81	81	87	81	77	29 84	29 87	29 88	29 89	4	8	14	7	SSW	S	NW	NNW			10
11	72	72	68	68	100	93	100	100	29 96	29 96	29 97	29 98	3	6	4	12	WNW	NNE	NNE	NNE	2	.80	11
12	68	71	72	76	66	58	56	56	30 12	30 16	30 16	30 16	9	8	5	5	NE	NNE	NE	S			12
13	69	72	76	77	97	93	79	80	30 17	30 16	30 16	30 14	6	7	3	7	NE	NE	SE	SE			13
14	75	78	80	84	91	83	76	68	30 00	29 98	29 95	29 92	13	15	15	13	SSW	SW	SW	SW			14
15	77	82	83	79	81	65	63	70	29 81	29 84	29 85	29 86	4	9	9	9	NNW	NW	NW	NW			15
16	71	76	80	83	62	62	56	54	29 95	29 97	29 98	29 95	10	-	-	7	NE	-	-	-			16
17	76	79	84	86	94	84	68	52	29 92	29 93	29 94	29 94	-	-	-	-	-	-	-	-			17
18	76	80	82	85	98	80	72	62	29 85	29 84	29 84	29 79	-	-	-	-	-	-	-	-			18
19	70	74	76	80	69	62	57	55	29 95	29 99	29 99	29 99	-	-	-	-	-	-	-	-			19
20	62	68	70	74	58	53	47	42	30 17	30 19	30 20	30 19	-	-	-	-	-	-	-	-			20
21	66	72	75	78	54	46	48	42	30 24	30 25	30 25	30 21	-	-	-	7	S	S	S	S			21
22	68	74	76	78	76	56	52	55	30 14	30 12	30 01	30 08	9	13	16	17	SW	SW	SW	SW			22
23	69	73	77	81	84	69	68	68	29.95	29.94	29.92	29.89	8	12	10	9	S	SSW	S	S			23
24	75	80	84	87	100	88	74	68	29.83	29.82	29.80	29.78	5	11	9	11	SSW	SW	S	SSW			24
25	80	78	86	88	98	95	80	76	29.78	29.78	29.78	29.76	6	7	10	6	S	ENE	NW	WNW		10	25
26	74	78	82	86	67	62	50	42	29.92	29.96	29.97	29.95	7	7	8	6	NNW	N	NNE	N			26
27	76	75	79	81	76	80	64	68	29.91	29.93	29.92	29.89	5	14	10	14	SSE	SSW	S	SSW		15	27
28	74	78	81	83	69	63	57	51	29 89	29 89	29 90	29 83	4	10	9	13	N	SSW	SSW	S			28
29	68	72	75	78	69	62	58	52	29 97	29 98	29 99	29 97	8	7	3	5	NE	N	S	S			29
30	66	72	77	80	84	76	66	56	30.04	30.04	30 04	30 01	10	9	7	5	NNE	NE	NNE	ENE			30
31	68	74	78	80	90	76	53	49	29 95	29 91	29.89	29 83	7	6	6	6	NE	NNE	ENE	ENE			31
MONTHLY VALUES																					3	05	

TABULATED BY APG MET TEAM

VERIFIED BY

REMARKS * Indicates time of day the charts were read, 0800, 1000, 1200 & 1400

SELWU Form 1010
1 Mar 65

USAEPG FORT HUACHUCA ARIZONA

METEOROLOGICAL DATA TABULATION SHEET

DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS

PERIOD 6 HOURS

LOCATION ABERDEEN PROVING GROUND, MD

SITE E M P RANGE ON SPESUTIE ISLAND

TIME ZONE EASTERN

MONTH AUGUST

YEAR 1965

DAY	TEMPERATURE °F * 8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN HG 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP IN INCHES		
1	67	68	68	75	96	96	96	90	29 93	29 91	29 86	29 82	13	15	13	8	SE	ESE	ESE	SE		.65	1
2	73	77	78	81	82	74	76	67	29 66	29 66	29 66	29 95	11	5	8	11	SSW	SW	S	S			2
3	66	72	76	76	71	59	57	57	30 86	30 89	30 90	30 90	9	16	15	17	S	SW	W	WSW			3
4	66	74	79	82	92	68	66	62	30 08	30 10	30 10	30 07	8	6	7	8	NNE	ENE	E	S	2	.60	4
5	68	71	73	78	100	90	81	64	30 11	30 14	30 15	30 14	8	8	6	6	ENE	NE	ENE	E		-	5
6	70	75	82	84	100	93	81	71	30 11	30 11	30 10	30 08	8	6	9	11	S	S	S	S			6
7	76	80	84	86	100	82	72	70	30 03	30.04	30 03	30 01	9	14	11	10	-	-	-	-			7
8	76	81	84	83	92	82	78	73	29 96	29 97	29 95	29 92	11	12	15	12	-	-	-	-		15	8
9	77	78	80	84	96	86	82	75	29 90	29 91	29 91	29 88	12	13	1 4	11	S	S	S	S			9
10	72	80	82	85	100	74	66	57	29 85	29 88	29 90	29 87	9	7	9	8	SW	SW	S	S		05	10
11	70	71	74	76	76	72	68	64	30 07	30 10	30 10	30 11	10	-	-	-	N	-	-	-		02	11
12	66	74	80	82	100	66	60	46	30 15	30 15	30 15	30 11	-	10	10	12	-	-	S	S			12
13	70	76	83	85	92	64	54	51	30 03	30 02	30 01	29 99	3	10	8	7	WNW	SW	WSW	WNW			13
14	72	77	81	84	96	78	70	64	29 97	29 96	29 96	29 95	6	3	5	5	NE	NNE	E	E		07	14
15	74	79	84	86	98	82	66	53	29 99	30 00	30 00	29 98	5	5	5	5	E	SE	E	E			15
16	77	80	84	89	100	83	70	49	29 94	29195	29 94	29 92	3	7	7	11	S	S	S	S			16
17	74	78	83	88	94	83	74	65	29 91	29 91	29 91	29 89	6	8	5	10	S	S	S	S			17
18	74	79	82	88	95	92	80	73	29 87	29 87	29 83	29 82	5	5	7	7	S	S	S	S			18
19	74	81	83	85	95	78	68	62	29 72	29 74	29 73	29 73	4	7	7	13	SW	SW	SW	WNW			19
20	70	73	87	89	81	57	47	43	29 95	29 99	30 01	30 02	15	14	10	10	NNW	NNW	NNW	NNW			20
21	66	72	77	80	78	60	52	42	30 13	30 16	30 17	30 14	7	3	3	3	ENE	E	SE	S		55	21
22	67	64	68	68	100	100	100	100	30.09	30.10	30 06	30 03	6	1	5	8	SSE	SSE	ESE	ESE		-	22
23	68	68	71	76	98	100	100	68	29.96	29.98	29.99	29.99	12	7	3	-	NE	NE	N	-			23
24	67	72	75	78	62	56	48	40	29.99	30.00	29.99	29.98	13	7	6	4	NE	NE	NE	E			24
25	69	72	74	75	90	79	64	58	30 00	30 01	30 01	30 00	4	1	6	5	NNE	S	S	S			25
26	70	73	79	81	93	93	84	70	29 89	29 89	29 89	29 84	5	1	7	12	S	S	S	S		20	26
27	71	81	83	83	90	67	61	60	29 89	29 92	29 93	29 83	5	5	8	9	S	S	S	S		07	27
28	77	80	86	87	94	86	57	52	29 77	29 76	29 75	29 73	8	8	18	17	SSW	SSW	SSW	SSW			28
29	53	59	65	69	58	56	56	50	30 14	30 16	30 15	30 12	5	7	5	9	S	WSW	NW	WSW			29
30	58	60	66	70	64	57	49	41	30 22	30 27	30 28	30 24	6	7	11	8	NW	NNW	N	N			30
31	61	68	72	74	58	52	52	52	30 26	30 26	30 24	30 21	8	12	13	15	S	S	S	S			31
MONTHLY VALUES																					4	36	

TABULATED BY APG MET TEAM

VERIFIED BY

REMARKS* Indicates time of day charts were read, 0800, 1000, 1200 & 1400

SELMU Form 1010
1 Mar 69

USAEPG FORT HUACHUCA ARIZONA

METEOROLOGICAL DATA TABULATION SHEET

DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS

PERIOD 6 HOURS

LOCATION ABERDEEN PROVING GROUND, MD

SITE E M P RANGE ON SPESUTIE ISLAND

TIME ZONE EASTERN

MONTH SEPTEMBER

YEAR 1965

DAY	* TEMPERATURE °F 8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN HG 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP IN INCHES	DAY
1	68	73	76	80	85	79	67	63	29.99	29 97	29 92	29 88	13	20	23	21	S	S	S	S	55	1
2	62	66	72	76	78	62	48	44	30 13	30 17	30 18	30 17	9	9	6	3	NW	NW	NW	NW		2
3	60	68	73	76	85	68	56	44	30 21	30 24	30 24	30 23	8	3	3	3	NW	ENE	E	ENE		3
4	64	69	74	75	98	72	48	48	30.30	30 30	30 33	30 33	8	7	8	7	-	-	-	-		4
5	60	66	70	76	98	76	58	52	30 34	30 34	30 35	30 29	5	5	4	3	-	-	-	-		5
6	61	66	71	75	96	73	50	46	30.34	30.34	30.32	30.29	3	3	2	1	-	-	-	-		6
7	65	70	77	82	93	72	54	40	30.20	30.20	30.19	30.16	5	5	3	1	-	NE	E	NE		7
8	64	74	78	82	100	58	58	48	30.05	30.05	30.04	30.01	0	3	3	2	-	SW	S	S		8
9	71	74	78	82	83	75	67	67	30.08	30.09	30.10	30.11	5	5	3	6	ENE	E	NE	NNW		9
10	72	76	79	87	75	68	63	48	30.05	30 06	30.04	30 01	4	8	6	4	-	S	S	S		10
11	74	82	83	82	100	64	64	70	30.06	30.09	30.11	30.13	0	4	5	4	-	NNE	NNE	N		11
12	68	68	69	68	90	88	85	84	30.22	30.24	30.24	30.24	7	8	6	7	ENE	ENE	E	NE	32	12
13	62	63	65	66	100	95	95	95	30.12	30.11	30.08	30.08	8	6	5	3	ENE	E	E	N	68	13
14	64	66	70	71	99	92	83	76	29.99	30.00	30.01	30.00	5	4	6	3	NNW	NNE	E	SE	05	14
15	64	68	74	78	94	88	86	80	29.95	29.93	29.83	29.82	-	7	8	3	-	S	-	-		15
16	70	75	78	80	84	60	56	48	30.01	30.07	30.08	30.10	6	8	4	3	NNE	N	E	N		16
17	68	70	74	78	80	80	75	71	30.29	30.32	30.34	30.32	12	8	7	2	E	NNE	NE	NE		17
18	70	73	76	80	95	95	90	82	30 30	30 30	30 29	30 26	3	5	6	6	SSW	SW	S	S		18
19	71	80	88	90	95	78	66	58	30.20	30.20	30.20	30.18	0	1	4	4	-	WSW	ESE	SSE		19
20	70	70	74	80	95	94	92	81	30.20	30.24	30.23	30.19	6	4	2	1	E	ESE	S	NNW		20
21	74	79	86	88	100	84	64	62	30 20	30 22	30 20	30 16	7	0	3	3	S	-	S	S		21
22	72	74	88	91	96	74	60	50	30 18	30 20	30 17	30 15	0	10	6	15	-	S	S	SW		22
23	74	80	82	85	94	84	67	63	30 12	30 11	30 08	30 03	9	12	12	14	S	S	SW	SW		23
24	73	75	80	75	88	84	76	80	29 88	29 86	29 82	29 74	5	5	6	11	N	E	S	S	1 21	24
25	55	59	63	64	67	55	47	45	29 88	29 93	29 95	29 95	10	13	18	16	NNW	NNW	NNW	NNW		25
26	49	59	64	67	73	59	47	47	30 15	30 16	30 16	30 14	12	8	6	5	NW	N	ESE	S		26
27	56	57	60	62	81	72	52	43	30 32	30 38	30 42	30 39	8	5	10	13	NE	NNE	NE	N		27
28	48	56	62	66	79	61	64	62	30 41	30 41	30 38	30 32	12	11	12	5	NE	E	ESE	E		28
29	54	60	64	68	100	83	75	61	30 12	30 13	30 13	30 10	7	5	9	7	NE	S	S	S		29
30	62	65	68	68	100	75	68	73	30 16	30 18	30 19	30 18	12	15	9	13	E	E	ESE	SE		30
MONTHLY VALUES																					2 76	

TABULATED BY APG MET TEAM

VERIFIED BY

REMARKS: * Indicates time of day the charts were read, 0800, 1000, 1200 & 1400

SELMU Form 1010
1 Mar 63

USAEPG FORT HUACHUCA ARIZONA

METEOROLOGICAL DATA TABULATION SHEET	DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS; PERIOD 6 HOURS	LOCATION ABERDEEN PROVING GROUND, MD; SITE E M P RANGE ON SPESUTIE ISLAND; TIME ZONE EASTERN	MONTH OCTOBER; YEAR 1965

DAY	TEMPERATURE °F 8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN HG 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP IN INCHES		
1	64	67	70	70	100	100	90	98	29 97	29 92	29 88	29 82	13	16	20	18	S	S	S	S		35	1
2	54	61	63	66	76	58	48	46	30 02	30 05	30 05	30 01	7	13	13	9	WSW	NNW	NNW	N			2
3	52	63	68	70	92	62	46	42	29 88	29 83	29 77	29 74	20	20	14	20	WSW	SW	SW	WSW			3
4	45	49	52	56	57	49	53	45	30 01	30 02	30 01	29 97	11	20	17	16	WNW	NW	NW	NW			4
5	39	45	48	51	67	51	44	38	30.14	30.17	30.18	30.12	8	11	13	8	NNW	NNW	WNW	NNW			5
6	38	51	57	57	100	49	44	43	30.17	30.19	30.15	30.10	2	8	7	12	SW	S	S	S			6
7	52	58	53	51	100	79	62	88	29 94	29 90	29.96	29.72	7	10	11	17	SE	SE	SE	SE			7
8	57	61	65	70	100	72	72	46	29 46	29.46	29 45	29.44	5	10	13	17	SW	WSW	SW	WSW		80	8
9	51	60	60	61	94	59	62	60	29.58	29.61	29.62	29.60	7	11	15	8	WSW	WSW	SW	WSW		11	9
10	51	53	61	61	96	98	64	60	29.70	29.74	29.74	29.76	10	8	14	9	WSW	WSW	W	NNW			10
11	43	52	59	63	100	68	51	50	29 99	30 01	30 02	30 00	5	7	8	12	WNW	W	NNW	SW			11
12	55	55	56	63	100	100	72	43	29 94	30 01	30 00	29 95	3	8	8	10	SW	WNW	NW	W			12
13	47	55	59	61	72	52	43	36	30 14	30 20	30 20	30 15	5	5	6	7	NNW	NNE	E	S			13
14	48	54	55	59	93	93	90	82	30 23	30 25	30 26	30 21	6	3	5	5	NE	NE	SE	N			14
15	59	63	69	73	100	98	86	76	30 15	30 16	30 14	30 10	5	-	-	-	SW	SW	SW	SW			15
16	59	63	69	71	100	95	54	46	30 13	30 16	30 18	30 16	7	8	10	7	NNE	NNE	NNE	N			16
17	47	51	57	59	76	70	62	54	30 38	30 41	30 44	30 42	9	9	6	5	E	E	E	E		.03	17
18	46	51	57	61	88	78	52	47	30 46	30 49	30 49	30 43	7	8	6	4	ENE	NE	ESE	SE		-	18
19	46	53	64	67	100	77	49	43	30.37	30 40	30 39	30 33	5	4	4	5	NNE	NNE	SE	E			19
20	52	59	68	74	96	82	57	49	30.27	30.26	30.25	30.19	8	6	4	5	NE	NE	ESE	SE			20
21	60	65	70	71	84	74	63	66	30.04	30 02	29 97	29 91	7	8	6	7	ENE	E	NE	ESE			21
22	63	64	66	68	100	97	87	80	29.74	29.75	29.73	29.67	6	7	7	6	ENE	SE	SE	S		03	22
23	56	59	62	-	100	71	59	46	29 47	29 46	29 43	29 38	4	6	7	8	S	WSW	NW	SW			23
24	44	48	52	52	79	62	48	42	29 67	29 72	29 75	29 75	9	10	13	14	N	NNW	NNW	NW			24
25	34	46	50	54	78	60	46	42	30 19	30 21	30 23	30 18	7	9	7	10	WNW	WNW	N	W			25
26	40	50	63	65	90	64	37	45	30 14	30 14	30 12	30 05	6	6	7	8	NW	WSW	W	S			26
27	44	58	59	61	79	60	48	44	30 01	30 03	30 03	30 01	7	8	10	13	WNW	W	NNW	NNW			27
28	44	54	56	56	76	52	40	36	29.97	29 97	30 04	30 03	7	15	11	9	N	NW	N	NNW			28
29	30	38	43	46	69	60	50	41	30.47	30.52	30.54	30 53	9	12	7	8	NNW	NNE	NNW	NNE			29
30	45	56	51	56	70	49	46	39	-	-	-	-	6	15	17	18	WNW	SW	SW	WSW			30
31	35	54	66	70	80	84	38	35	-	-	-	-	4	15	12	14	WSW	SW	WSW	SW			31
MONTHLY VALUES																					1	32	

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DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS

PERIOD 6 HOURS

LOCATION ABERDEEN PROVING GROUND, MD

SITE E M P RANGE ON SPESUTIE ISLAND

TIME ZONE EASTERN

MONTH NOVEMBER

YEAR 1965

DAY	TEMPERATURE °F * 8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN HG 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP IN	DAY
1	44	53	55	57	64	48	38	35	-	30.14	30.14	30.11	15	15	18	20	WNW	NNW	NW	NW		1
2	34	41	46	46	56	48	40	41	30.47	30.50	30.50	30.47	12	11	7	7	NNE	NNE	NNE	S		2
3	50	53	57	65	62	56	50	37	30.38	30.36	30.33	30.25	17	14	15	12	WSW	SW	SW	WSW		3
4	59	72	77	77	65	35	35	34	30.15	30.18	30.19	30.18	8	12	18	12	SW	W	NW	NW		4
5	40	46	52	54	64	52	50	48	30.57	30.64	30.61	30.55	9	7	4	8	NE	ESE	S	N		5
6	44	53	59	61	84	68	56	50	30.42	30.42	30.38	30.33	1	8	10	8	S	SE	SW	SW		6
7	49	54	64	69	100	86	64	50	30.23	30.22	30.18	30.14	2	3	8	6	N	SE	E	WSW		7
8	53	54	56	60	94	91	90	87	30.15	30.12	30.07	30.00	7	7	3	3	SE	SE	SE	ESE	03	8
9	49	52	53	54	56	54	45	42	30.06	30.12	30.13	30.11	10	13	14	12	N	N	N	N		9
10	31	36	39	48	71	70	64	54	30 34	30 37	30 36	30 29	7	7	5	5	E	E	NE	NE		10
11	41	42	43	45	100	100	100	100	30 28	30 30	30 30	30 28	8	5	7	5	E	ENE	ENE	ENE	.06	11
12	47	48	53	55	90	86	77	72	30 31	30 33	30 30	30 28	7	17	13	8	E	ESE	SE	ESE		12
13	49	51	54	56	100	100	100	97	30 04	30 04	30 01	29 98	-	-	-	-	-	-	-	-	10	13
14	41	51	53	52	88	47	42	40	30 14	30 19	30 19	30 19	-	-	-	-	-	-	-	-		14
15	31	37	41	43	64	56	49	47	30 33	30 34	30 60	30 27	8	5	6	4	-	ESE	SE	SSE		15
16	52	56	54	52	77	71	100	100	29 77	29 70	29 68	29 62	17	20	8	18	S	SW	SW	SW	20	16
17	41	44	47	46	48	45	42	40	29 50	29 53	29 49	29 50	25	20	30	20	WNW	W	W	WNW		17
18	35	41	44	48	48	45	41	37	29 76	29 84	29 83	29 83	20	-	-	17	WNW	-	-	WNW		18
19	35	42	46	49	60	48	44	44	29 99	30 05	30 03	30 00	11	8	12	7	W	NW	NW	NW		19
20	32	42	50	50	100	74	48	50	30 12	30 11	30 05	29 99	3	5	8	9	ENE	SE	SW	S		20
21	41	49	49	47	84	70	62	82	29 83	29 84	29 82	29 78	4	5	7	6	SW	N	SW	ENE	05	21
22	44	45	46	48	100	100	100	100	29 62	29 63	29 62	29 61	8	9	7	6	NE	NNE	N	N	28	22
23	39	52	51	53	100	70	66	63	29 83	29 82	29 79	29 74	6	8	7	8	W	SW	SW	SW		23
24	33	42	50	50	91	70	53	52	30.05	30 08	30 07	30 06	8	7	15	12	-	W	WNW	WNW		24
25	32	38	48	50	95	84	62	56	30 20	30 20	30 18	30 11	8	7	9	7	ESE	SE	SSW	SSW		25
26	42	48	54	55	100	71	60	62	30 10	30 14	30 12	30 06	1	7	5	0	NNW	ESE	E	-	03	26
27	64	[illegible]	64	68	80	100	100	33	29 55	29 59	29 56	29 57	20	9	16	26	SSW	SSW	W	W	09	27
28	40	48	-	-	60	50	44	49	29 76	29 75	29 70	29 63	17	8	7	7	-	-	-	-		28
29	26	37	38	38	60	45	45	46	29 87	29 91	29 90	29 89	7	16	17	15	-	-	-	WNW		29
30	27	35	40	39	68	59	47	49	30.12	30 15	30 15	30 13	6	7	5	13	NW	N	NNW	NNW		30
MONTHLY VALUES																					84	

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1 Mar 65

USAEPG FORT HUACHUCA ARIZONA

METEOROLOGICAL DATA TABULATION SHEET

DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS

PERIOD 6 HOURS

LOCATION ABERDEEN PROVING GROUND, MD

SITE E M P RANGE ON SPESUTIE ISLAND

TIME ZONE EASTERN

MONTH DECEMBER

YEAR 1965

DAY	TEMPERATURE °F * 8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN HG 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP IN INCHES		DAY
1	27	38	42	43	70	50	44	39	30 30	30 33	30 31	30 25	7	8	10	10	WNW	NW	NW	W			1
2	30	46	50	52	79	44	50	40	30 24	30 25	30 21	30 15	6	11	11	13	W	WSW	SSW	SW			2
3	41	44	49	48	80	66	54	61	30 14	30 17	30 08	30 02	7	3	5	6	NE	ESE	NNE	N			3
4	39	47	53	50	84	64	45	39	29 73	29 75	29 71	29 72	9	10	15	23	WSW	WSW	W	NW			4
5	36	39	43	48	57	62	54	52	29 88	29 83	29 73	29 68	11	7	10	15	WSW	WSW	SW	SW			5
6	40	45	50	47	57	44	34	35	29 66	29 68	29 68	29 68	7	10	13	10	SW	W	NW	NNW			6
7	27	30	35	41	54	48	38	40	30 15	30 21	30 25	30 22	21	25	17	14	NN	NNW	NNW	N			7
8	26	40	45	46	86	64	50	44	30 18	30 12	30 06	30 03	8	12	14	7	S	S	SSW	SSW			8
9	30	38	45	46	92	74	44	46	30 31	30 36	30 36	30 31	-	5	4	6	NNW	ENE	NE	NNE			9
10	27	43	48	54	100	70	56	42	30 26	30 31	30 31	30 27	3	3	2	2	W	E	NE	ENE			10
11	38	40	41	43	84	81	82	78	30 16	30 14	30 06	30 04	6	6	2	5	NE	ENE	NE	NNE		.03	11
12	41	41	42	42	100	100	100	100	30.06	30.07	30.04	29.98	9	8	8	9	ENE	ENE	ESE	E			12
13	47	48	49	52	100	100	100	100	29 71	29.71	29.66	29.64	5	3	5	1	ESE	NNE	W	W		68	13
14	41	45	50	54	100	100	87	52	29.78	29.83	29.81	29.77	3	4	6	7	SW	W	WNW	WNW			14
15	36	42	46	48	76	54	46	51	29.94	29.95	29.95	29.91	6	7	10	7	NW	WNW	NW	NNW			15
16	34	42	50	47	100	90	65	66	29.97	30.02	30 02	29 99	5	7	5	4	NNE	NNE	ESE	S			16
17	37	50	51	45	100	56	50	51	29.87	29.89	29.87	29.88	3	13	18	17	WNW	NW	NW	WNW			17
18	24	31	36	39	64	60	44	42	30.07	30.06	30 01	29.94	10	8	6	6	W	NW	W	WNW			18
19	25	29	35	-	76	68	51	44	29.91	29.92	29.86	29.83	15	9	8	7	WNW	NW	NW	WSW			19
20	20	22	26	29	64	56	49	44	29.90	29.94	29.88	29.84	11	9	7	8	WNW	NW	W	NW			20
21	24	30	36	35	68	57	54	54	29 91	29 97	29 96	29 94	7	7	7	8	NNE	NNE	NNE	N			21
22	20	33	44	46	97	80	55	42	30 26	30 33	30 32	30 29	4	6	6	-	SW	WSW	WSW	WSW			22
23	30	40	46	50	85	69	63	54	30 32	30 35	30 35	30 30	7	7	9	10	W	SW	SSW	SSW			23
24	38	45	54	58	100	90	55	49	30 22	30 22	30 19	30 14	5	4	12	13	N	SW	SW	SW			24
25	66	66	66	67	78	90	95	90	29 73	29 69	29 60	29 53	25	28	26	25	S	S	S	S		.48	25
26	33	32	35	38	53	45	42	35	29 99	30 10	30 11	30 14	41	31	27	25	N	NNW	NW	NNW			26
27	15	22	25	29	56	56	54	51	30 47	30 52	30 48	30 42	13	8	6	7	N	ENE	SE	SSW			27
28	32	41	43	42	64	50	46	44	30 49	30 55	30 56	30 50	7	10	11	8	WNW	NW	NW	NNW			28
29	25	36	41	-	100	100	70	60	30 52	30 51	30 46	30 42	5	11	21	12	W	SSW	SW	SW			29
30	29	31	45	49	100	100	64	60	30 32	30 32	30 26	30 19	2	5	8	7	NE	SW	SW	SW			30
31	32	50	61	66	100	87	62	56	30 19	30 19	30 12	30 06	8	12	6	7	SW	SW	SW	SSW			31
																	MONTHLY VALUES				1	.19	

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USAEPG FORT HUACHUCA ARIZONA

METEOROLOGICAL DATA TABULATION SHEET

DATA OBTAINED FROM CONTINUOUSLY RUNNING CHART RECORDS

PERIOD 6 HOURS

LOCATION ABERDEEN PROVING GROUND, MD.
SITE E.M.P. RANGE ON SPESUTIE ISLAND
TIME ZONE EASTERN

MONTH JANUARY
YEAR 1966

DAY	TEMPERATURE °F *8	10	12	14	% RELATIVE HUMIDITY 8	10	12	14	BAROMETRIC PRESS IN MB 8	10	12	14	WIND SPEED MPH 8	10	12	14	WIND DIRECTION 8	10	12	14	PRECIP. IN INCHES
1	58	54	68	64	92	100	68	70	016.8	018.6	018.4	019.2	5	8	11	7	N	W	NW	NNW	-
2	46	47	44	45	100	88	100	100	023.7	023.7	022.3	019.6	16	10	14	15	E	E	E	ESE	.23
3	46	44	46	48	100	100	100	33	015.9	018.0	018.3	018.7	3	7	9	33	NNW	W	SW	WNW	.02
4	32	40	44	43	69	56	52	51	033.3	035.0	034.8	032.7	7	7	8	14	W	N	SW	SSW	
5	29	34	37	40	100	94	88	74	029.7	030.2	028.5	027.1	2	5	5	5	NW	NE	SE	NNE	.12
6	43	45	46	45	100	100	100	100	006.4	005.7	003.9	002.9	15	11	11	5	ENE	NE	NW	N	.54
7	34	43	45	46	92	66	70	63	012.2	012.2	010.9	010.2	3	4	10	6	SW	NNW	S	SSW	
8	32	31	29	27	53	50	48	44	011.5	012.5	012.7	013.4	29	31	34	38	NW	NW	NW	NW	
9	20	25	29	31	58	48	43	41	029.8	030.8	030.5	029.3	11	19	15	11	W	NW	NW	N	
10	32	39	41	44	69	50	47	40	023.7	022.7	020.8	017.8	5	18	17	8	S	SW	SW	SSW	
11	27	29	31	33	50	44	43	38	023.5	024.7	024.1	023.5	15	12	17	25	NNW	WNW	NW	NW	
12	19	23	26	28	57	49	41	35	031.7	032.0	031.4	029.1	8	21	16	12	NW	N	NNW	N	
13	22	28	31	32	55	46	46	49	025.2	024.6	021.7	019.1	9	9	10	17	SSW	SSW	S	S	
14	34	37	38	40	70	34	56	56	015.6	016.3	016.0	014.2	8	22	14	10	NW	NNW	NNW	N	
15	23	31	34	36	100	90	78	60	018.0	018.4	016.8	014.9	2	2	7	1	N	W	SSW	ESE	
16	19	23	26	30	58	44	41	39	014.5	015.2	013.5	013.0	16	22	20	18	NNW	NW	NW	NW	
17	30	32	33	36	54	53	50	45	017.0	018.0	017.4	016.2	16	27	24	15	WNW	NW	NW	NW	
18	26	30	32	34	65	50	46	42	018.7	018.8	017.6	014.9	5	13	13	20	NNW	NNW	NNW	NW	
19	27	30	36	36	57	54	48	47	015.2	016.4	014.5	014.2	10	13	20	18	W	NW	NNW	NW	
20	31	36	40	42	69	60	54	50	020.1	023.0	022.9	021.1	12	14	13	10	N	N	N	N	
21	32	33	39	41	77	73	55	47	026.4	027.4	026.8	025.6	11	8	10	8	N	N	N	NNW	
22	30	32	35	36	80	78	70	73	025.1	025.3	022.8	020.7	7	7	10	10	ENE	E	E	ENE	.15
23	34	33	33	33	100	100	98	98	992.2	992.4	994.3	995.7	30	33	29	28	NW	NW	NW	WNW	.65
24	27	31	32	32	57	51	49	50	017.0	018.3	019.8	019.5	15	11	22	22	W	NW	NW	NW	
25	22	25	26	27	60	60	58	61	027.2	027.6	027.5	026.4	10	14	13	14	NNW	N	N	N	
26	22	23	21	21	62	62	61	92	023.5	022.0	020.0	018.5	13	18	17	20	ENE	NE	NE	NNE	.15
27	20	23	27	30	72	72	58	45	010.3	011.0	010.8	007.6	22	19	24	17	NNE	NNE	NW	NNW	.02
28	10	13	15	17	47	41	40	33	018.3	020.0	020.0	019.5	8	15	17	16	NNW	WNW	WNW	WNW	
29	8	13	16	17	51	48	47	48	020.8	021.2	019.4	015.3	6	7	3	7	WNW	NW	NNW	NNW	.25
30	16	18	18	18	96	96	94	94	985.3	986.0	987.4	989.2	28	18	31	37	NW	WNW	W	W	.60
31	14	19	22	25	75	72	-	-	013.0	012.4	013.5	014.2	22	23	23	20	W	WNW	WNW	W	

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VERIFIED BY

MONTHLY VALUES 2.73

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13 ABSTRACT

This report describes the instrumented range facility designated the Electromagnetic Propagation Range as established by the Ballistic Research Laboratories (BRL)in support of fundamental research in the near-earth meteorological environment. It includes a description of the multi-channel, high-speed, digital data acquisition system, the types of instrumentation used for obtaining meteorological data, methods of instrument and sensor calibration, and typical results of field programs. Tabulated data and photographs of all parts of the system are included.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Electromagnetic Propagation Range						
Near-Earth Meteorological Environment						
Meteorological Sensors						
High Speed Digital Data Recorder						
Meteorological Sensor Calibration						

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